DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 18: ADVANCED QUANTUM MECHANICS - II

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Quantum Mechanics-II DSE 18	4	3	1	0	Quantum Mechanics (DSC 14), and Advanced Quantum Mechanics-I (DSE 13)

Course Objectives

This course aims to:

- Introduce and develop approximation methods for solving quantum systems where exact solutions are not possible, including both time-independent and time-dependent approaches.
- Strengthen understanding of the interaction picture and its role in quantum dynamics.
- Equip students with the tools of scattering theory, including formal techniques like the Lippmann–Schwinger equation, Green's functions, and the Born approximation.
- Provide a conceptual and mathematical foundation for advanced topics in quantum physics such as quantum field theory, quantum optics, and condensed matter physics.

Learning Outcomes

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

- Apply key approximation methods including time-independent perturbation theory, and the variational method to compute approximate energy levels and wavefunctions in stationary quantum systems.
- Analyze quantum systems under time-dependent perturbations using the interaction picture, derive transition probabilities, and apply Fermi's Golden Rule to systems with a continuum of final states.
- Formulate and solve quantum scattering problems using ket formalism, Lippmann–Schwinger equations, and the Born approximation.
- Perform partial wave analysis and interpret scattering processes through phase shifts, S-matrix properties, and the optical theorem.

SYLLABUS OF DSE 18
THEORY COMPONENT
(Credits: 3; Hours: 45)

Unit I **(14 Hours)**

Approximation Methods for Stationary Systems
Time-independent perturbation theory up to second order perturbation for non- degenerate case with applications to perturbed potential wells, linear harmonic oscillator with perturbed force constant ($k \rightarrow (1+\varepsilon)k$), charged harmonic oscillator in a weak electric field. First order perturbation for anharmonic oscillator with cubic and quartic terms.
Degenerate systems with application to spin-orbit coupling and fine structure of hydrogenic atom, Zeeman effect (weak and strong field).
Variational method and its applications to ground state of simple harmonic oscillator and Helium atom, electron interaction energy and extension of variational method to excited states.

Unit II **(14 Hours)**

Approximation Methods for time-dependent perturbations
Interaction picture. Time-dependent perturbation theory (up to first order perturbation). Transition probabilities, transition to a continuum of final states, Fermi's Golden Rule. Application to constant and harmonic perturbations. Sudden and adiabatic approximations

Unit III **(17 Hours)**

Scattering: Wave packet description of scattering, scattering amplitude, differential and total cross section. Lippmann-Schwinger Equations, Formal treatment of scattering by Green's function method. Born approximation and applications to central potentials. Definition and properties of S-Matrix.
Partial wave analysis: Asymptotic behaviour of partial waves, Phase shifts and angular momentum decomposition, Optical theorem and conservation of probability.

References

Essential Readings

1. *Introduction to Quantum Mechanics*, D.J. Griffith, Pearson Education (2005).
2. *Modern Quantum Mechanics*, J. J. Sakurai and Jim Napolitano, Cambridge University Press (2021).
3. *Quantum Mechanics,* Eugene Merzbacher, John Wiley and Sons, Inc (2004).
4. *Quantum Mechanics: Theory and Applications*, Ajoy Ghatak and S. Lokanathan, Laxmi Publications (2019).
5. *Quantum Mechanics,* B. H. Bransden and C. J. Joachain, Prentice Hall (2000).

Additional Readings

11. *Principles of Quantum Mechanics*, R. Shankar, Springer (2008).
12. *Introduction to Quantum Mechanics*, Volume-I and II, C. Cohen-Tannoudji, Bernard Diu, and Franck Laloë, Wiley-VCH (2020).
13. *Introduction to Quantum Mechanics*, R. H. Dicke and J. P. Wittke, Addison-Wesley Publications (1966).

14. *Quantum Mechanics*, Leonard I. Schiff, Tata McGraw Hill (2010).
15. *Quantum Mechanics*, Walter Greiner, Springer (2001).
16. *Quantum Mechanics*, Albert Messiah, Dover Publications Inc. (2014)
17. *Scattering Theory of Waves and Particles*, R. G. Newton, Springer-Verlag Berlin and Heidelberg GmbH & Co. (2014

Advisory

The course is essential for several courses offered in the one-year M.Sc. program and is also included in the syllabi of various competitive examinations, including CSIR-NET, JEST, and GATE.
Colleges are advised to offer this as a Discipline Specific Elective (DSE). Students who intend to pursue postgraduate studies or appear for competitive exams are strongly encouraged to choose this course as a DSE.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 19: ADVANCED STATISTICAL MECHANICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Statistical Mechanics DSE 19	4	3	1	0	

Course Objectives

- To introduce the fundamental principles and mathematical framework of statistical mechanics.
- To understand the concept of ensembles (microcanonical, canonical, and grand canonical) and their application to physical systems.
- To introduce quantum statistical concepts such as the density matrix and its applications.
- To introduce basic concepts of interacting system with the Ising model

This course provides a strong foundation for advanced study in theoretical and applied physics, and prepares students for research or technical roles in fields involving thermodynamic systems, statistical modelling and complex systems.

Learning Outcomes

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

- Understand fundamental concepts and principles of statistical mechanics including macrostates, microstates, and phase space, and their significance in describing physical systems.
- Formulate the microcanonical ensemble and apply it to model systems such as classical and quantum harmonic oscillators and ideal gases.
- Explain the grand canonical ensemble, including equilibrium with a particle-energy reservoir.
- Establish the relationship between canonical and grand canonical partition functions and use them to evaluate thermodynamic properties of systems with variable particle numbers.
- Describe the basic principles of quantum statistical mechanics including the concept of quantum ensembles and density matrix
- Describe basic principles of statistical mechanics of interacting systems with the help of Ising model

<u>SYLLABUS OF DSE 19</u>
<u>THEORY COMPONENT</u>
(Credits: 3; Hours: 45)

Unit I **(8 hours)**

Review of Microcanonical and Canonical Ensembles
Macrostates, microstates, phase space, microcanonical ensemble (no derivation), partition function and its use in finding various thermodynamic quantities (no derivation). Examples of systems with finite and infinite energy levels using microcanonical and canonical ensemble approaches.

Unit II **(12 hours)**

Grand Canonical Ensemble
Equilibrium between a system and a particle-energy reservoir, a system in grand canonical ensemble, physical significance of various statistical quantities, density and energy fluctuations in grand canonical ensemble: correspondence with other ensembles, relation between canonical partition function and grand canonical partition function.

Unit III **(12 Lectures)**

Quantum Mechanical Ensembles
Basic idea of quantum-mechanical ensemble theory. Density matrix of microcanonical, canonical and grand canonical ensembles, Particle in a box and quantum harmonic oscillator.

Unit IV **(13 Lectures)**

Interacting Systems
Introduction to the Ising model. Exact solution of Ising model in one dimension. Mean field approximation.

<u>References</u>

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. Statistical Physics of Particles, Mehran Kardar (Cambridge University Press, 2007)
4. Statistical and Thermal Physics: An Introduction, Michael J R Hoch, 2nd Edition (CRC Press, 2021)

Additional Readings

1. Statistical Mechanics An advanced course with problems and solutions R. Kubo, First Edition (Elsevier, 2014)
2. Thermodynamics and Statistical Mechanics, Greiner, Neise and Stocker, Springer 1995.
3. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill, Inc., 1967
4. Statistical and Thermal Physics: With Computer Applications, Harvey Gould and Jan Tobochnik

Advisory

The course is essential for several courses offered in the one-year M.Sc. program and is also included in the syllabi of various competitive examinations, including CSIR-NET, JEST, and GATE.
Colleges are advised to offer this as a Discipline Specific Elective (DSE). Students who intend to pursue postgraduate studies or appear for competitive exams are strongly encouraged to choose this course as a DSE.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 20: 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 20	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 20
THEORY COMPONENT
(Credits: 2; 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), The 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.

References

Essential Readings

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

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.

PRACTICAL COMPONENT: DIGITAL SIGNAL PROCESSING
(Credits: 2; 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 $0 \leq n \leq 50$.
2. Write a program to compute the convolution sum of a rectangle signal (or gate function) with itself for N = 5

$$x(n) = rect\left(\frac{n}{2N}\right) = \prod \left(\frac{n}{2N}\right) = \{1 \quad -N \leq n \leq N \; 0 \quad otherwise$$

3. An LTI system is specified by the difference equation: y(n)=0.8y(n-1)+x(n)
   (a) Determine $H(e^{iw})$
   (b) Calculate and plot the steady state response y(n) to $x(n) = \cos\cos(0.5\pi n)\,u(n)$
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:
   $x(n) = \{1,1,1,1\} = \{1 \;\; 0 \leq n \leq 3 \; 0 \;\; otherwise$
   ↑
   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

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

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

References

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.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 21: GROUP THEORY AND ITS APPLICATIONS

Course Title and Code	Credits	Credit Distribution of the Course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Group Theory and Application DSE 21	4	3	1	0	DSC-1 Mathematical Physics I DSC-4 Mathematical Physics II DSC-7 Mathematical Physics III, DSC-11 Solid State Physics DSC- 14 Quantum Mechanics I or equivalent courses. Knowledge of Linear Algebra is recommended

Course Objectives

- To introduce students to the fundamental structures and operations of group theory.
- To develop the ability to construct and classify groups, subgroups, and their representations.
- To prepare students to apply group theoretical methods to problems in quantum mechanics, molecular physics, and crystallography.
- To provide a rigorous foundation in both finite and continuous groups relevant to advanced physics.

Learning Outcomes

After completing this course, students will be able to:

- Identify and classify groups, subgroups, and conjugacy classes.
- Understand and use homomorphisms, isomorphisms, and quotient structures.
- Construct and analyze matrix representations of groups.
- Apply character theory and the Great Orthogonality Theorem.
- Analyze symmetries in quantum systems using SU(2), SU(3), and SO(n) groups.
- Interpret and utilize point groups and space groups in solid-state and molecular systems.

SYLLABUS OF DSE 21
THEORY COMPONENT
(Credits: 3; Hours: 45)

Unit I **(13 Hours)**

Basics of Group Theory
Symmetry and Groups, Properties of groups, Abelian and non-abelian groups. Cayley Table and Diagram. Concept of Subgroup, cyclic subgroups, center of a group. Cosets and Lagrange's Theorem. Direct Sum and Direct Product of Groups.
Homomorphism and Isomorphism of Groups. Kernel and Image of Homomorphism. Representations of Groups.

Unit II **(12 Hours)**

Finite Groups and Representations
Permutation Groups, Cayley's Theorem (Statement only). Normal subgroups, Quotient Groups and Simple groups. Conjugate Subgroups and conjugacy classes. Dihedral Groups. Classes, Unitary representations, Reducible and Irreducible representations of finite groups. Schur's Lemma. Great Orthogonality Theorem and Character Table. Dimensionality Theorem. Direct product of representation and representation of Direct Product Groups.

Unit III **(10 Hours)**

Continuous Groups
U (1) group, Lie Groups and Generators of Group. Lie Algebra and Jacobi Identity. Orthogonal Lie Groups. Rotation group in 2 and 3 dimensions: SO(2), SO(3) and their generators. Unitary Lie Groups: SU(2), SU(3) and their generators. Homomorphism of SU(2) and SO(3). Homogenous Lorentz Group.

Unit IV **(10 Hours)**

Applications in Physics
SU(2) and quantum spin: Irreducible representation of SU(2) and their relation to spin. Direct Product of representations and Addition of Angular momentum. Clebsch-Gordan Decomposition and Coefficients.
Crystal Symmetry: Point Groups and examples, Point group C_{4v} and its character table. Significance of character table in studying crystal properties.
Space Groups and examples, Space Group P4mm corresponding to the point group C_{4v}.

References

Essential Readings

1. Mathematical Methods for Physicists, H. J. Weber and G. B. Arfken, Elsevier (2010).
2. Mathematical Methods for Physics and Engineering, K. F. Riley, M. P. Hobson, S. J. Bence, Cambridge University Press (2006).
3. Mathematical Physics with Applications, Problems and Solutions, V. Balakrishan, Ane Books (2017).

4. Group Theory and its Applications to Physical Problems, by Morton Hamermesh, Dover Publications (1989).
5. Introduction to Mathematical Physics: Methods & Concepts, Chun Wa Wong, Oxford University Press (2012).
6. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2000).
7. Groups, Representations and Physics, H. F. Jones, Taylor & Francis (1998).
8. Group Theory in Physics: An Introduction to Symmetry Principles, Group Representations, and Special Functions in Classical and Quantum Physics, Wu-Ki Tung, World Scientific Publishing Co. Pte. Ltd. (2003).
9. Group Theory in a Nutshell for Physicists, A. Zee, Princeton University Press (2016).

Additional Readings

1. Introduction to Mathematical Physics: Methods and Concepts, Chun Wa Wong, Oxford University Press (2012).
2. Group Theory: A Physicist's Survey, Pierre Ramond, Cambridge University Press (2010).
3. A Physicist's Introduction to Algebraic Structures: Vector Spaces, Groups, Topological Spaces and More, Palash B Pal, Cambridge University Press (2019).
4. Schaum's outline of Group Theory, B. Baumslag and B. Chandler, McGraw Hill Education (1968).
5. Contemporary Abstract Algebra, Joseph A Gallian, 9th ed, Brooks/Cole Cengage Learning (2017).
6. Group Theory in a Nutshell for Physicists, A. Zee, Princeton University Press (2016).
7. Group Theory in Physics: An Introduction with a Focus on Solid State Physics, Jörg Bünemann, Springer Nature (2024).
8. Group Theory in Physics: An Introduction, J. F. Cornwell, Academic Press (1997).
9. Classical groups for physicists, B.G. Wybourne, Wiley
10. Chemical Applications of Group Theory, F A Cotton, John Wiley and Sons (1990).
11. Lie Algebras in Particle Physics, H. Georgi, CRC Press (1999).
12. Group Theory in Physics: An Introduction with a Focus on Solid State Physics, Jörg Bünemann, Springer Nature (2024).

DISCIPLINE SPECIFIC ELECTIVE COURSE - DSE 22: 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 22	4	3	1	0	

Course Objective

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 22
THEORY COMPONENT
(Credits: 3; 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

(A) 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.

(B) 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 Tutorials

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).

DISCIPLINE SPECIFIC ELECTIVE COURSE - DSE 23: PLASMA PHYSICS

Course Title and Code	Credits	Credit Distribution of the Course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Plasma Physics DSE 23	4	3	1	0	DSC 13 - Electromagnetic Theory (Sem. V) and DSC 8 - Thermal Physics (Sem. III) of this program or its equivalent.

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 23
THEORY COMPONENT
(Credits: 3; 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.

DISCIPLINE SPECIFIC ELECTIVE COURSE - DSE 24: SENSORS AND DETECTORS

Course Title and Code	Credits	Credit Distribution of the Course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Sensors and Detectors DSE 24	4	3	0	1	DSC 13 - Electromagnetic Theory (Sem. V) and DSC 8 - Thermal Physics (Sem. III) of this program or its equivalent.

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 24
THEORY COMPONENT
(Credits: 3; Hours: 45)

Unit I **(5 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.

Unit II **(8 Hours)**

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 III **(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 IV **(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 V **(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).

References

Essential Readings

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

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

PRACTICAL COMPONENT: SENSORS AND DETECTORS
(Credits: 1; 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

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