CENTRAL UNIVERSITY OF SOUTH BIHAR

Master of Science (M.Sc.) Physics Programme

Syllabus

(Effective from Academic Session 2022-2023)

Department of Physics

SCHOOL OF PHYSICAL AND CHEMICAL SCIENCES

Two Years M.Sc. in Physics
Semester Wise Course Structure
(Total 80 Credits for Two Year M.Sc.)

Course Code	Course Title	Credit	
	Semester-I	**C**	**L/T/P**
PHY81DC20104	Mathematical Physics	4	4/0/0
PHY81DC20203	Classical Mechanics	3	3/0/0
PHY81DC20304	General Physics Lab. – I	4	0/0/4
PHY81DE20403	Electronics	3	3/0/0
PHY81DE20502	Molecular Physics	2	2/0/0
PHY81SW20604	Elective – I (From other department)/ Swayam Course*	4	4/0/0
PHY81ME20700	Fundamentals of Indian Knowledge Systems (Mandatory)	0	2/0/0
	Total Credit	**20**	
Course Code	**Course Title**	**Credit**	
	Semester - II	**C**	**L/T/P**
PHY82DC20104	Quantum Mechanics	4	4/0/0
PHY82DC20205	Introduction of Research Methodology	4	4/0/0
PHY82DC20304	General Physics Lab. – II	4	0/0/4
PHY82DE20402	Classical Electrodynamics	2	2/0/0
PHY82DE20502	Nuclear and Particle Physics	2	2/0/0
PHY82DE20602	Solid State Physics	2	2/0/0
PHY82SW20704	Elective – II (From other department)/ Swayam Course*	4	4/0/0
PHY82DE20800	Indian Knowledge Systems in modern context (Mandatory)	0	2/0/0
	Total Credit	**22**	

Course Code	Course Title	Credit	
Semester-III (Specialization in Condensed Matter Physics)		**C**	**L/T/P**
PHY91DC20103	Condensed Matter Physics	3	3/0/0
PHY91DC20204	Condense Matter Physics Lab – I	4	0/0/4
PHY91DE20303	Experimental Techniques for Material Science	3	3/0/0
PHY91DE20404	Solid State Devices	4	4/0/0
PHY91DC20502	Dissertation* Credit will be counted in 4th sem	2** will be counted in 4th sem	
	Elective (from CMP Bucket)	3	3/0/0
	Elective (from CMP Bucket)	3	3/0/0
Total Credit		**20**	
Course Code	**Course Title**	**Credit**	
Semester-IV (Specialization in Condensed Matter Physics)		**C**	**L/T/P**
PHY92DC20104	Advanced Condensed Matter Physics	4	4/0/0
PHY92DC20204	Condensed Matter Physics Lab – II	4	0/0/4
PHY92DC20306	Dissertation	6 (3+3*)	0/0/6
	Elective (from CMP Bucket)	4	4/0/0
Total Credit		**18**	
Course Code	**Course Title**	**Credit**	
Semester-III (Specialization in Nuclear and Particle Physics)		**C**	**L/T/P**
PHY91DC21104	Advance Nuclear Physics	4	4/0/0
PHY91DC21204	Nuclear & Particle Physics Lab. – I	4	4/0/0
PHY91DE21304	Introduction of Astroparticles	4	4/0/0
PHY91DE21404	Nuclear Reactor Physics	4	4/0/0
PHY91DE21504	Experimental Techniques in Nuclear and Particle Physics	4	4/0/0

PHY91DC21602	Dissertation (Credit will be counted in 4th sem) Entering dessietation evolution Presentation- evolution for 1* credit	2** will be counted in 4th sem	
Total Credit		**20**	
Course Code	**Course Title**	**Credit**	
Semester - IV (Specialization in Nuclear and Particle Physics)		**C**	**L/T/P**
PHY92DC21104	Advanced Particle Physics	4	4/0/0
PHY92DC21204	Nuclear & Particle Physics Lab. – II	4	0/0/4
PHY92DE21304	Particle Accelerator Physics	4	4/0/0
PHY92DC21406	Dissertation	6 (4+2*)	0/0/6
Total Credit		**18**	

Elective Bucket

S. No.	Course Code	Course Name
1	PHY81OE22104[†]	Biography of Indian Scientists
2	PHY82DE22202	Statistical Mechanics
3	PHY91OE22304[†]	Elements of Ancient Indian Sciences
4	PHY91DE22403	Crystallography, Crystal Structures and Diffraction Techniques
5	PHY91DE22503	Material Science
6	PHY91DE22603	Alloy Design and Development
7	PHY91DE22703	Fundamentals of Scanning Probe Microscop
8	PHY92DE22804	Low temperature physics
9	PHY92OE22904[†]	Ancient Indian Sciences
10	PHY92DE23004	Renewable Energy : Solar and Hydrogen

11	PHY92DE23104	Nanoscience and Nanotechnology
12	PHY92DE23204	Physics of Magnetism and Spintronics
13	PHY92DE23304	Nanoelectronics
14	PHY92DE23404	Statistical Analysis Techniques in Nuclear and Particle Physics

* The department will suggest a few courses from Swayam based on availability of Physics related courses at the portal.

† The open elective courses may be floated by the department in any of the odd or the even semesters (as the case may be) irrespective of the specific semester mentioned in course structure/syllabus/course code. Also the students may opt for these courses irrespective of the semester they are registered in (provided they have enough knowledge of the prerequisites).

Note: Minimum 10 students for elective course

Course Title: Mathematical Physics

Course Code	PHY81DC20104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	I	**Contact Hours**	60 (L)Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

1. Student should be able to understand basic theory of Linear Algebra
2. Student should be able to understand basic theory of Matrix algebra.
3. Student should be able to understand basic theory of Special functions.
4. Student should be able to understand basic theory of Complex Analysis.
5. To learn mathematical tools required to solve physical problem.
6. To understand mathematical concepts related to physics.

Course Learning Outcomes:

1. Upon completion of this course, the student should able to:
2. Have a good grasp of the basic elements of complex analysis, including the important integral theorems. Students will be able to determine the residues of a complex function and use the residue theorem to compute certain types of integrals.
3. Students will understand the applications of matrix algebra.
4. Students will understand the applications of vector space.
5. Students will understand the applications of special functions.
6. Apply mathematical ideas and models to problems.
7. Apply mathematical problems and solutions in aspect of science and technology.
8. Demonstrate proficiency in mathematics and mathematical concept needed for a proper understanding of physics
9. Demonstrate the ability to justify and explain their thinking and approach.
10. Gain experience to investigate the real world problems.

Course Contents:

Unit-1

Linear vector spaces and operators: Vector spaces and subspaces, Linear dependence and independence, Inner product, Orthogonality, linear operators, Matrix representation, Similarity transformations, Characteristic polynomial of a matrix, Eigen values and eigenvectors, Self adjoint and Unitary transformations, Eigen values and eigenvectors of Hermitian and Unitary transformations, diagonalization.

(25 % Weightage)

Unit-2

Vector analysis and curvilinear co-ordinates: Gradient, Divergence and Curl operations, Vector Integration, Gauss' and Stokes' theorems, Curvilinear co-ordinates, Gradient, Curl, divergence and Laplacian in spherical polar and cylindrical polar co-ordinates. Definition of tensors, contravariant and covariant components of tensors.

(25 % Weightage)

Unit-3

Ordinary differential equations and Special Functions: Linear ordinary differential equations, Series solutions – Frobenius'method, Series solutions of the differential equations of Bessel, Legendre, Leguerre and Hermite polynomials.

(25 % Weightage)

Unit-4

Complex analysis and Group theory: Functions of a complex variable, Analytic functions, Cauchy- Riemann relations, Cauchy's theorem, Cauchy's integral formula, Taylor and Laurent expansions, residue theorem, Evaluation of definite integrals, elementary idea of group theory.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Vector spaces and subspaces, Linear dependence and independence, Inner product, Orthogonality, linear operators
6-10	Matrix representation, Similarity transformations, Characteristic polynomial of a matrix, Eigen values and eigenvectors
11-15	Self adjoint and Unitary transformations, Eigen values and eigenvectors of Hermitian and Unitary transformations, diagonalization.
16-20	Gradient, Divergence and Curl operations,
21-25	Vector Integration, Gauss' and Stokes' theorems,
26-30	Curvilinear co-ordinates, Gradient, Curl, divergence and Laplacian in spherical polar and cylindrical polar co-ordinates. Definition of tensors, contravariant and covariant components of tensors.
31-35	Linear ordinary differential equations, Series solutions – Frobenius'method,
36-40	Series solutions of the differential equations of Bessel, Legendre polynomials.
41-45	Series solutions of the differential equations of Leguerre and Hermite polynomials.

46-50	Functions of a complex variable, Analytic functions, Cauchy-Riemann relations, Cauchy's theorem
51-55	Cauchy's integral formula, Taylor and Laurent expansions
56-60	residue theorem, Evaluation of definite integrals, elementary idea of group theory

Essential Readings:

1. Mathematical Methods of Physics - J. Mathews and R. L. Walker, Second Edition, Addison- Wesley.
2. Mathematical Methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012

Additional/Advance/Further Readings:

1. Matrices and Tensors in Physics - M. R. Spiegel, Schaum Series
2. Linear Algebra – Seymour Lipschutz, Schaum Outlines Series
3. Matrices and Tensors in Physics - A.W. Joshi, Wiley Eastern Ltd, 1975
4. Vector Analysis - M. R. Spiegel, Schaum Series
5. Introduction to Dynamics – I. Percival and D. Richards, Cambridge University Press.
6. Complex functions – M. R. Spiegel, Schaum Series.
7. Mathematical Physics - P.K.Chattopadhyay, Wiley Eastern Ltd.1990.
8. Linear Algebra and Group theory for Physicists – K. N. Srinivasa Rao.

Course Title: Classical Mechanics

Course Code	PHY81DC20203	**Credits**	3
L+T+P	3+0+0	**Course Duration**	One Semester
Semester	I	**Contact Hours**	45(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

1. To acquaint the students with the basic concepts of system of particles and centre of mass.
2. To acquaint the students with the basic concepts of conservation of linear momentum, energy and angular momentum.
3. To acquaint the students with the basic concepts of Lagrangian Formulation.
4. To orient the student with the simple applications of the Lagrangian formulation.
5. To orient the student with central forces including Keplar problem.
6. To acquaint the students with the basic concepts of scattering in a central force field.
7. To make the students understand the basic concepts of motion in non-central reference frames and coriolis force.
8. To acquaint the students with the basic concepts of rigid body dynamics.
9. To acquaint the students with Euler's equations of motion for a rigid body.
10. To acquaint the students with the basic concepts of normal modes.
11. To orient the student with the simple applications normal modes and normal frequencies.
12. To orient the student with Hamiltonian formulation.
13. To acquaint the students with the Canonical transformation.
14. To make the students understand the basic concepts of Poisson brackets and properties of Poisson brackets.

Course Learning Outcomes:

1. After completion of the course the learners will be able to:
2. To derive the centre of mass for a system of particles.
3. To apply the conservation of linear momentum, energy and angular momentum.
4. To describe basic concepts of Lagrangian Formulation.
5. To solve the problem with the simple applications of the Lagrangian formulation.
6. To solve the problem of central forces including Keplar problem.
7. To describe the basic concepts of scattering in a central force field.
8. To describe the basic concepts of motion in non-central reference frames and coriolis force.
9. To describe the basic concepts of rigid body dynamics.
10. To derive the Euler's equations of motion for a rigid body.
11. To describe the basic concepts of normal modes.
12. To solve the simple applications of normal modes and normal frequencies.
13. To solve the problem with Hamiltonian formulation.
14. To describe the Canonical transformation.
15. To describe the basic concepts of Poisson brackets and properties of Poisson brackets.

Course Contents:

Unit-1

System of particles: Center of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, energy and angular momentum. Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the second kind, uniqueness of the Lagrangian, Simple applications of the Lagrangian formulation: 1. Single free particle in (a) Cartesian co-ordinates, (b) plane polar co-ordinates; 2. Atwood's machine; 3.bead sliding on a uniformly rotating wire in a forcefree space; 4. Motion of block attached to a spring ; 5. Simple pendulum. Symmetries of space time: Cyclic coordinate, Conservation of linear momentum, angular momentum and energy.

(25 % Weightage)

Unit-2

Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion), equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force).

Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering, center of mass and laboratory co-ordinate systems, transformations of the scattering angle and cross-sections between them. Motion in non-central reference frames: Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum.

(25 % Weightage)

Unit-3

Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia, classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body.

Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula.

(25 % Weightage)

Unit-4

Hamiltonian formulation: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Examples of (a) the Hamiltonian of a particle in a central force field, (b) the simple harmonic oscillator, cyclic co-ordinates and conservation theorems, derivation of Hamilton's equations from variational principle. Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton-Jacobi method

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	System of particles: Center of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, energy and angular momentum.
3-5	Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the second kind, uniqueness of the Lagrangian
6-10	Simple applications of the Lagrangian formulation: 1. Single free particle in (a) Cartesian co-ordinates, (b) plane polar co-ordinates; 2. Atwood's machine; 3.bead sliding on a uniformly rotating wire in a force free space; 4. Motion of block attached to a spring ; 5. Simple pendulum.
11-13	Symmetries of space time: Cyclic coordinate, Conservation of linear momentum, angular momentum and energy.
14-16	Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion), equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force).
17-19	Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering, center of mass and laboratory co-ordinate systems, transformations of the scattering angle and cross-sections between them.

20-22	Motion in non-central reference frames: Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum.
23-25	Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia
26-29	Classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body.
20-34	Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula.
35-39	Hamiltonian formulation: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Examples of (a) the Hamiltonian of a particle in a central force field, (b) the simple harmonic oscillator, cyclic co-ordinates and conservation theorems, derivation of Hamilton's equations from variational principle.
40-45	Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton-Jacobi method

Essential Readings:

1. Classical mechanics, H. Goldstein, C. Poole, J. Saflco, 3rd edition, Pearson Education Inc. (2002)
2. Classical mechanics, K. N. Srinivasa Rao, University Press (2003).

Additional/Advance/Further Readings:

1. Classical mechanics, N. C. Rana and P. S. Joag, Tata McGraw-Hill (1991).
2. Classical dynamics of particles and systems, J. B. Marian, Academic Press (1970)
3. Introduction to classical mechanics, Takwale and Puranik, Tata McGraw-Hill (1983).
4. Classical mechanics, L. D. Landau and E. M. Lifshitz, 4th edition, Pergamon press (1985).

Course Title: General Physics Lab – 1

Course Code	PHY81DC20304	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	I	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to

1. enhance the understanding of the students of procedural knowledge of condensed matter physics.
2. enhance the ability of the students to explain the processes and applications related to condensed Matter physics.
3. develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. develop interest and motivate the master students towards experiment research.
5. enhance the scientific understanding of advanced instruments which will help them for research.
6. develop ability to work together.
7. develop an ability to express themselves coherently and logically.
8. develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Comprehend the concepts through experiments.
2. express the basic concepts of Condensed Matter physics in more general language.
3. Design and develop the instruments for advanced studies.
4. Evaluate theoretical calculations using experimental observations.

5. Having a clear understanding of the subject related concepts and of contemporary issues.
6. Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

Course Contents:

1. Addition, Subtraction and Binary to BCD conversion
2. JK Flip-Flop and up-down counter
3. Zeeman Effect
4. Negative Feedback Experiment
5. Experimental set-up for measurement of resistivity by four probe method (Four Probe Method)
6. Compton Effect
7. Field effect transistor (FET)
8. Experimental set-up for verification of Faraday's and Lenz's Law of induction
9. Op-amps and its application
10. Faraday Effect
11. Polarization of light using Quarter-Wave Plate
12. Frank-Hertz experiment
13. Design of CE Amplifier
14. Design of Regulated Power Supply
15. Arithmetic Logic Unit
16. Experimental set-up for study of Faraday effect and Verdet's constant using He-Ne Laser
17. Determination of e/m by Thomson's method (Bar Magnet Method)
18. Michelson 's interferometer

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Electronics

Course Code	PHY81DE20403	**Credits**	3
L+T+P	3+0+0	**Course Duration**	One Semester
Semester	I	**Contact Hours**	45(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

1. To acquaint the students with the basic concepts of p-n junction.
2. To acquaint the students with the basic concepts of BJT.
3. To acquaint the students with the basic concepts of JFET.
4. To orient the student with the MOSFET.
5. To orient the student with LED.
6. To acquaint the students with the basic concepts of operational amplifier.
7. To acquaint the students with the basic concepts of inverting and non-inverting configurations.
8. To orient the student with the simple applications of operational amplifiers.
9. To acquaint the students with the basic concepts of Digital circuits.
10. To acquaint the students with simplification of SOP and POS equations.
11. To acquaint the students with the basic concepts simplification using Karnaugh Map technique.
12. To orient the student with the basic concepts of flip flops, registers, and counters.
13. To orient the student with Digital to Analog converters.
14. To acquaint the students with the Analog to Digital converters.
15. To make the students understand the basic concepts of Read Only Memory and Random Access Memory.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. To describe the basic concepts of p-n junction.
2. To describe the basic concepts of BJT.
3. To describe the basic concepts of JFET.
4. To describe the basics concepts of the MOSFET.
5. To describe the working of LED.
6. To describe the basic concepts of operational amplifier.
7. To identify the difference between inverting and non-inverting configurations.
8. To describe the simple applications of operational amplifiers.
9. To describe the basic concepts of Digital circuits.
10. To simplify SOP and POS equations.
11. To simplify using Karnaugh Map technique.
12. To describe the basic concepts of flip flops, registers, and counters.
13. To describe Digital to Analog converters.
14. To describe Analog to Digital converters.
15. To describe the basic concepts of Read Only Memory and Random Access Memory.

Course Contents:

Unit-1: Operational amplifiers

Block diagram of an operational amplifier – Characteristics of an ideal operational amplifier – comparison with 741 – Operational amplifier as a open loop amplifier - Limitations of open loop configuration – Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain. Applications of op-amp: Linear applications – Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier – inverting and non-inverting configurations, subtractor, difference summing amplifier, ideal and practical Differentiator, Integrator. Non – linear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers. basic comparator, zero-crossing detector, Schmitt trigger, Oscillators

(35 % Weightage)

Unit-2: Digital techniques

Boolean laws and theorems, simplification Karnaugh Map technique (4 variables)- conversion of binary to Grey-code. Flip flops: Latch using NAND and NOR gates- RS flip flop, clocked RS flip flop, JK flip flop, JKmaster slave flip flop - racing –Shift Registers basics - Counters: Ripple counters truth table-timingdiagram, Synchronous counters-truth table-timing diagram, Decade counter. Visual displays:Single-element displays, seven-segment displays, decoder logic. Digital to Analog converters: ladder andweighted resistor types. Analog to digital Converters-counter method, successive approximation and dualslope converter. Application of DAC and ADC and applications

(35 % Weightage)

Unit-3: Microprocessor

The ideal microprocessor, architecture of microprocessor, organisation of microprocessor, features of Intel 8085, 8085 functional pin description, 8085 CPU architecture, introduction to 8051 microcontroller basics.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Block diagram of an operational amplifier – Characteristics of an ideal operational amplifier – comparison with 741 – Operational amplifier as a open loop amplifier - Limitations of open loop configuration
5-8	Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain.
9-12	Applications of op-amp: Linear applications – Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier – inverting and non-inverting configurations, subtractor, difference summing amplifier, ideal and practical Differentiator, Integrator.
13-16	Non – linear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers. basic comparator, zero-crossing detector, Schmitt trigger, Oscillators
17-20	Boolean laws and theorems, simplification Karnaugh Map technique (4 variables)- conversion of binary to Greycode.
21-24	Flip flops: Latch using NAND and NOR gates- RS flip flop, clocked RS flip flop, JK flip flop, JKmaster slave flip flop - racing –Shift Registers basics - Counters: Ripple counters truth table-timingdiagram,
25-28	Synchronous counters-truth table-timing diagram, Decade counter. Visual displays:Single-element displays, seven-segment displays,
28-32	decoder logic. Digital to Analog converters: ladder andweighted resistor types. Analog to digital Converters-counter method,
32-36	successive approximation and dualslope converter. Application of DAC and ADC and applications
36-40	The ideal microprocessor, architecture of microprocessor, organisation of microprocessor,
41-45	features of Intel 8085, 8085 functional pin description, 8085 CPU architecture, introduction to 8051 microcontroller basics.

Essential Readings:

1. Op-Amps and Linear Integrated Circuits, Ramakant A Gayakwad, (Third Edition, 2004), Eastern Economy Edition.

2. Operational Amplifiers with Linear Integrated Circuits, William Stanley, (1988), CBS Publishers and Distributors.

3. Linear Integrated Circuits, D Roy Choudhury and Shail Jain, ((1991), New Age International (P) Limited.

4. Digital principles and applications, Donald P Leach and Albert Paul Malvino, (Fifth Edition, 2002), Tata McGraw Hill.

5. Digital systems, Principles and applications, Ronald J Tocci and Neal S Widmer, (Eighth Edition, 2001), Pearson Education. Physics of Semiconductor Devices, Shur, PHI P
6. Microprocessor Architecture Programming & Applications – R.S. Gaonkar.
7. Microprocessor 8085: Architecture, Programming, & Interfacing – A. Wadhwa

Additional/Advance/Further Readings:

1. Bevington P. and Robinson D. K. "Data Reduction and Error Analysis for the Physical Sciences", 2002, 3rd edition, ISBN-13: 978-0072472271
2. Bohm G. Zech, G. "Introduction to Statistics and Data Analysis for Physicists", http://www-library.desy.de/preparch/books/vstatmpengl.pdf
3. John E. Freund's "Mathematical Statistics with Applications", 2012, 8th edition, ISBN-13:978-0321807090
4. Feigelson, E. Babu, J. "Modern Statistical Methods for Astronomy: With R Applications", 2012, ISBN-13: 978-0521767279
5. Integrated Electronics by Jacob Millman, Christos Halkias, Tata McGraw-Hill Education Private Limited, 2009

Course Title: Molecular Physics

Course Code	PHY81DE20502	**Credits**	2
L+T+P	2+0+0	**Course Duration**	One Semester
Semester	I	**Contact Hours**	30(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

1. To gain knowledge about the basic concepts and methodology in molecular physics.
2. To understand in detail the structure of atoms and molecules by studying various spectroscopic methods.
3. To study the spectroscopic techniques for analyzing different molecular spectra.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Analyze different atomic structure and will be able to understand fine- structure and hyperfine-structure spectra.
2. Recall different coupling schemes and their interactions with magnetic and electric fields.
3. Explain rotational and IR spectroscopy and apply the techniques of microwave and infrared spectroscopy to analyze the structure of atoms and molecules.
4. Apply the principle of Raman spectroscopy and its applications in various disciplines of science & technology.
5. Explain different magnetic and electron spin resonance spectroscopic techniques and its applications.
6. Demonstrate the contemporary issues on atomic and molecular physics.
7. Evaluate problems related to different atomic & molecular systems by carrying out the project work.

Course Contents:

Unit-1

Molecular Structure and Molecular Spectra :Types of molecules, Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Born-Oppenheimer approximation. Morse potential energy curve, Molecules as vibrating rotator, Vibration spectrum of diatomic molecule, PQR branches. Elementary discussion of Raman, ESR and NMR spectroscopy, chemical shift.

(50 % Weightage)

Unit-2

Infrared spectroscopy: The vibrating diatomic molecule. The diatomic vibrating-rotator spectra of diatomic molecules Raman Spectroscopy: Introduction, Pure rotational Raman spectra, Vibrational Raman Spectra, Nuclear Spin and intensity alternation in Raman spectra, Isotope effect, Raman Spectrometer.

(50 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Types of molecules, Electronic, rotational, vibrational and Raman spectra of diatomic molecules.
5-8	Selection rules. Born-Oppenheimer approximation.,
9-12	Morse potential energy curve, Molecules as vibrating rotator, Vibration spectrum of diatomic molecule.
13-15	PQR branches. Elementary discussion of Raman, ESR and NMR spectroscopy, chemical shift.
16-20	The vibrating diatomic molecule. The diatomic vibrating-rotator spectra of diatomic molecules.
21-24	Raman Spectroscopy: Introduction, Pure rotational Raman spectra, Vibrational Raman Spectra.
25-28	Nuclear Spin and intensity alternation in Raman spectra.
28-30	Isotope effect, Raman Spectrometer.

Essential Readings:

1. Fundamentals of Molecular Spectroscopy by Colin N. Banwell and Elaine M. McCash – McGraw Hill Education, 4th Edition (1994).
2. Elements of Spectroscopy by S.L. Gupta, V. Kumar and R.C. Sharma – PragatiPrakashan, 27th Edition (2015).
3. Spectroscopy by Sham K. Anand and Gurdeep R. Chatwal – Himalaya publishing House, 5th Edition (2013).

Additional/Advance/Further Readings:

1. Spectrometric identification of organic compounds by Robert M. Silverstein, Francis X. Webster and David J. Kiemle – Johnwiley & Sons Inc., 7th Edition (2005).
2. Molecular Spectroscopy by Jack D. Graybeal – McGraw Hill Inc., 2nd Edition (1993).
3. Organic Spectroscopy (English language book society student editions) by William Kemp – Palgrave Macmillan, 3rd Edition (1991).

Course Title: Fundamentals of Indian Knowledge Systems

Course Code	PHY81ME20700	**Credits**	Non-credit Mandatory
L+T+P	Non-credit Mandatory	**Course Duration**	One Semester
Semester	I	**Contact Hours**	30(L) Hours

Course Type	Mandatory Elective Non-credit Course
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Value Addition, Indian Knowledge Systems
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	Attendance / Group discussion / Presentation / Viva etc.

Course Objectives:

The main objective of this course is to make students grasp the correct understanding of different fundamental concepts, present throughout the Indian Knowledge Systems, in proper contexts.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. explain the meaning of different ideas of indian knowledge systems in proper contexts.
2. differentiate between proper and improper interpretation of certain ideas in indian knowledge systems.
3. appreciate the importance of different traditions in indian knowledge systems.

Course Contents:

Different knowledge systems in the world and their importance; Purusha & Prakriti - The ultimate truth and the observable world, Expansion of self as the observable world, Apparent diversity from underlying unity; Classification of Indian Knowledge Systems - Paraa & Aparaa Vidyaa; The objects of human pursuit - Dharma, Artha, Kaama & Moksha; Dharma - The fundamental basis for all Indian knowledge systems; Shaastra - The prescriptive nature of Indian discourses; Yajna - Daily life activities as Yajna; Varna & Aashrama; The causal nature of universe - Karma Siddhaanta & Punarjanma; The concept of time - Kaalachakra; Pramaana - Means of acquiring knowledge; Darshana in contrast to Philosophy; Bhikshaatana - two way flow of knowledge; Veda and Vedaanga, Upanishad, Puraana, Itihaasa; Comparative study of the oral and the scriptural traditions; Falsification of word-to-word translation for knowledge transfer among different systems, Sanskrita for technical discourse.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1	Different knowledge systems in the world and their importance

2-5	Purusha & Prakriti - The ultimate truth and the observable world, Expansion of self as the observable world, Apparent diversity from underlying unity.
6-7	Classification of Indian Knowledge Systems - Paraa & Aparaa Vidyaa
8-9	The objects of human pursuit - Dharma, Artha, Kaama & Moksha
10-12	Dharma - The fundamental basis for all Indian knowledge systems
13-14	Shaastra - The prescriptive nature of Indian discourses
15-16	Yajna - Daily life activities as Yajna
17-19	Varna & Aashrama
20-22	The causal nature of universe - Karma Siddhaanta & Punarjanma
23-24	The concept of time - Kaalachakra
25-26	Pramaana - Means of acquiring knowledge
27-28	"Darshana in contrast to Philosophy; Bhikshaatana - two way flow of knowledge; Comparative study of the oral and the scriptural traditions; Falsification of word-to-word translation for knowledge transfer among different systems, Sanskrita for technical discourse.
29-30	Veda and Vedaanga, Upanishad, Puraana, Itihaasa

Essential Readings:

1. Upanishad Ganga; TV Series
2. The Wonder that is Sanskrit - Sampad & Vijay; Auro Publications
3. Sanskrit Non-translatables: The importance of Sanskritizing English - Rajiv Malhotra & Satyanaranaya Dasa Babaji

Additional/Advance/Further Readings:

1. Different ancient indian texts

Course Title: Quantum Mechanics

Course Code	PHY82DC20104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course will teach the basic principles of Quantum Mechanics. Students will learn theoretical principles and problem solving skills applied to the quantum world of atoms, molecules and photons. The knowledge obtained in this class will serve as a foundation for further advanced classes on specialized topics such as Condensed Matter Physics, Nuclear and Particle Physics and various electives.

1. impart knowledge of postulates of quantum mechanics
2. introduce students about how to write and solve the Schrodinger's equation for model systems to obtain the energy eigen states.
3. acquaint the students with the concept of angular momentum and its importance in understanding the systems with spherical symmetry
4. familiarize the student with the time-independent and time-dependent approximation methods for solving real problems
5. introduce the relativistic description of quantum mechanics and the necessity for field-based quantum theory

Course Learning Outcomes:

Upon completion of this course, the student should:

1. master the central aspects of basic quantum mechanics: basic postulates and central theorems, eigenfunctions and eigenvalues, expansions in terms of eigenfunctions, stationary and nonstationary states, square-well potential, harmonic oscillator, the hydrogen atom,
2. have learned how to use the Dirac formalism, and how to apply operator algebra to quantize angular momentum and the harmonic oscillator,
3. be familiar with spin formalism and addition of angular momenta,
4. comprehend the theory and the implications of identical particles, especially ideal Fermi and Bose gases,

5. understand the main concepts of perturbation theory.
6. understand the relativistic formulation of quantum mechanics, need for field formalism, and basic relativistic field theories.

Course Contents:

Unit-1

Wave mechanics: Schrodinger equation, Stationary states, one-dimensional potentials (infinite square well, finite square well, Delta-function potential, Harmonic Oscillator), Scattering in one-dimension.
Linear vector spaces, Linear operators, Matrix representation of operators, Eigenvalues and Eigenvectors, Inner products, Linear functional , Adjoint operators, Hermitian and Unitary operators, Dirac notation, Uncertainty principle and compatible operators, Complete set of commuting operators.

(25 % Weightage)

Unit-2

Angular Momentum and Spin, Tensor product states, Algebra of angular momentum, Central potential Hamiltonians (free particle, infinite spherical well, three-dimensional isotropic oscillator, hydrogen atom), Addition of Angular Momentum with applications in spin-orbit coupling and hyperfine splitting in hydrogen atom.
Identical particles: Exchange degeneracy, Symmetrization Postulate, Constructing symmetric and antisymmetric states, system of identical non-interacting particles, the Pauli's exclusion principle and the Periodic table.

(25 % Weightage)

Unit-3

Approximation methods:
Time-independent perturbation theory for non- degenerate and degenerate levels, Application to ground state of an harmonic oscillator and Stark effect in Hydrogen, Variation method, Application to ground state of Helium atom, WKB approximation.
Time Dependent Perturbation Theory Time dependent perturbation theory, Constant and harmonic perturbations, Transition probabilities, Fermi's-Golden rule, Semi classical treatment of an atom with electromagnetic radiation, Selection rules for dipole radiation.

(25 % Weightage)

Unit-4

Scattering Theory: Kinematics of Scattering Process: differential and total cross-section -Asymptotic from of scattering wave function. Scattering amplitude by Green's method. Born approximation method and screened potential and square well potential as examples - Partial wave analysis and phase shift-Optical Theorem- Relationship between phase shift and Potential. Scattering by Hard sphere. Relativistic Quantum Mechanics Klein Gordon Equation, Plane wave solution and Equation of continuity, Probability density- Dirac Equation, alpha, beta- matrices, Plane wave solution, significance of negative energy states. Spin of Dirac particle Relativistic particle in central potential Total Angular Moment, Particle in a magnetic field-Spin Magnetic moment

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic

1-9	Wave mechanics: Schrodinger equation, Stationary states, one-dimensional potentials (infinite square well, finite square well, Delta-function potential, Harmonic Oscillator), Scattering in one-dimension
10-15	Linear vector spaces, Linear operators, Matrix representation of operators, Eigenvalues and Eigenvectors, Inner products, Linear functional , Adjoint operators, Hermitian and Unitary operators, Dirac notation, Uncertainty principle and compatible operators, Complete set of commuting operators
16- 19	Angular Momentum and Spin, Tensor product states, Algebra of angular momentum
20-23	Central potential Hamiltonians
24-27	Addition of Angular Momentum with applications
28-30	Identical particles:Exchange degeneracy, Symmetrization Postulate, Constructing symmetric and antisymmetric states, system of identical non-interacting particles, the Pauli's exclusion principle and the Periodic table
31-38	Time-independent perturbation theory for non- degenerate and degenerate levels, Variation method and its applications, WKB approximation
39-45	Time Dependent Perturbation Theory Time dependent perturbation theory, Constant and harmonic perturbations, Transition probabilities, Fermi's-Golden rule, Semi classical treatment of an atom with electromagnetic radiation, Selection rules for dipole radiation
46-51	Scattering Theory: differential and total cross-section -Asymptotic from of scattering wave function. Scattering amplitude by Green's method, Born approximation method, Partial wave analysis
52-55	Klein-Gordon Equation, Plane wave solution and Equation of continuity, Probability density
56-60	Dirac Equation, alpha, beta- matrices, Plane wave solution, significance of negative energy states. Spin of Dirac particle Relativistic particle in central potential

Essential Readings:

1. Griffiths, David J., Introduction to Quantum Mechanics. Third Edition, Pearson Prentice Hall.
2. Zettile, Nouredine. Quantum Mechanics: Concepts and Applications, Second Edition (Indian Adaptation), Wiley
3. Bjorken, J. D. and Drell, S. D., Rellativistic Quantum Mechanics, 1st Edition, McGraw-Hill Book Company.

Additional/Advance/Further Readings:

1. Merzbacher E., Quantum Mechanics, Third Edition, John Wiley and Sons, 1998.
2. Quantum Mechanics Vol I & II – C. Cohen-Tannoudji, B. Diu and F. Laloe, Second Edition, Wiley Interscience Publication, 1977
3. Quantum Mechanics- L.I. Schiff, Third Edition, Mc Graw Hill Book Company, 1955.
4. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
5. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
6. Principles of Quantum Mechanics - R. Shankar, Second Edition, Springer, 1994.

Course Title: Research Methodology

Course Code	PHY82DC20204	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	II	Contact Hours	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. Research Methodology.
2. Statistical Methods.
3. Errors in Observation & calculations.
4. Numerical Methods.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. describe the Types of Research.
2. explain the Statistical Methods.
3. Students will learn Errors in Observation & calculations.
4. Students will learn Research Literature in Physics.

Course Contents:

Unit-1

Research: Meaning, Definition, Methodology, Research process, Criterion of good research Types of Research: Fundamental or Basic, Applied, Historical, Descriptive, Analytical quantitative, qualitative, Conceptual Experimental, Case study Research Design: Meaning, Concepts, need, designs for different types of research; library, laboratory and field research; Advantages of Designing Research Research Problem and Developing Research proposal: Selection of research area and topic, statement of the research problem, its scope, steps involved in defining the problem. Literature Search: Reviewing related literature, referencing, abstracting, Computer search, bibliography, evaluation of the problem. Defining concepts, objectives, basic assumptions, delimitations and limitations of the problem, Statement of Hypothesis.

(25 % Weightage)

Unit-2

Statistical Methods Variables: Independent and dependent variables, qualitative and quantitative variables, discrete and continuous variables, confounding variables, methods of controlling variables. Measurement of variables. Sampling: Meaning, Characteristics of a good sample design, steps in sampling design, types, advantages Techniques of Data Collection: Primary data; Questionnaire, Schedules, Interview observation & other methods,Secondary data: Reliability, suitability & Adequacy of data. Processing and Analysis of Data: Processing Operations: Editing, coding, classification and tabulation of data, Elements of Data Analysis, Role of statistics in Data Analysis. Statistical Tables Report writing: Types, Format.

(25 % Weightage)

Unit-3

Errors in Observation & calculations Probability: Basic Aspects, probability of combination of events, probability of random variables, distribution of random variable Statistical Methods: Measures of Central tendency- Mean, Median, Mode, Arithmetic, Geometric and Harmonic mean. Measures of Dispersion: Range, Mean Deviation, Variance, Standard Deviation, Coefficient of variation Regression and Correlation: Least square method of fitting a regression line, curvilinear regression, correlation methods, correlation coefficient. Test of Significance: t-test, chi-test, ANOVA, f-test Hypothesis

Numerical Methods Common distribution functions: Binomial probability distribution, Poisson distribution and normal distribution etc. Errors in Experiments: Errors in observations; random errors, systematic errors; Normal law of errors; Average error, Standard error and probable error; significant figures; percentage error. Errors in Calculations: Approximate numbers and significant figures; Rounding of numbers; Absolute and relative errors, Relation between relative Error and significant figures; General formula for Errors; Application of Error formulas to fundamental operations of Arithmetics

(25 % Weightage)

Unit-4

Research Literature in Physics Abstracts and Journals and Physics, Electronic Journals, major libraries, arXivs, Data books and other resources of information, subscribing journals in Physics Scientific Writing: Organization and writing a research paper, short communication, review articles, monographs, technical and survey reports, authored books, edited books, dissertation, thesis Patents and patent writing, type of different applications, Disclosure for an invention in the thesis IPR (Intellectual Property Rights), Types, objectives, Limitations, Agreements, Laws and Government Enforcement.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Research: Meaning, Definition, Methodology, Research process, Criterion of good research Types of Research: Fundamental or Basic, Applied, Historical, Descriptive, Analytical quantitative, qualitative, Conceptual Experimental, Case study Research Design: Meaning, Concepts, need, designs for different types of research; library, laboratory and field research;

5-15	Advantages of Designing Research Research Problem and Developing Research proposal: Selection of research area and topic, statement of the research problem, its scope, steps involved in defining the problem. Literature Search: Reviewing related literature, referencing, abstracting, Computer search, bibliography, evaluation of the problem. Defining concepts, objectives, basic assumptions, delimitations and limitations of the problem, Statement of Hypothesis.
16-20	Statistical Methods Variables: Independent and dependent variables, qualitative and quantitative variables, discrete and continuous variables, confounding variables, methods of controlling variables. Measurement of variables. Sampling: Meaning, Characteristics of a good sample design, steps in sampling design, types, advantages
21-24	Techniques of Data Collection: Primary data; Questionnaire, Schedules, Interview observation & other methods,Secondary data: Reliability, suitability & Adequacy of data.
25-28	Processing and Analysis of Data: Processing Operations: Editing, coding, classification and tabulation of data, Elements of Data Analysis, Role of statistics in Data Analysis. Statistical Tables Report writing: Types, Format.
28-32	Cross-Sections, Exoergic and Endoergic Reactions, Behaviour of Cross-Sections near Threshold, Inverse Reaction, Qualitative Features of Nuclear Reactions
32-36	Errors in Observation & calculations Probability: Basic Aspects, probability of combination of events, probability of random variables, distribution of random variable Statistical Methods: Measures of Central tendency- Mean, Median, Mode, Arithmetic, Geometric and Harmonic mean. ,
36-40	Measures of Dispersion: Range, Mean Deviation, Variance, Standard Deviation, Coefficient of variation Regression and Correlation: Least square method of fitting a regression line, curvilinear regression, correlation methods, correlation coefficient. Test of Significance: t-test, chi-test, ANOVA, f-test Hypothesis ,
41-44	Numerical Methods Common distribution functions: Binomial probability distribution, Poisson distribution and normal distribution etc. Errors in Experiments: Errors in observations; random errors, systematic errors; Normal law of errors; Average error, Standard error and probable error; significant figures; percentage error. Errors in Calculations: Approximate numbers and significant figures; Rounding of numbers; Absolute and relative errors, Relation between relative Error and significant figures; General formula for Errors; Application of Error formulas to fundamental operations of Arithmetics
45-48	Research Literature in Physics Abstracts and Journals and Physics, Electronic Journals, major libraries, arXivs, Data books and other resources of information, subscribing journals in Physics .
49-52	Scientific Writing: Organization and writing a research paper, short communication, review articles, monographs, technical and survey reports, authored books, edited books, dissertation,
53-56	thesis Patents and patent writing, type of different applications,
57-60	Disclosure for an invention in the thesis IPR (Intellectual Property Rights), Types, objectives, Limitations, Agreements, Laws and Government Enforcement

Essential Readings:

1. Agrawal, B.L., Basic statistics, New Delhi: New Age publishers.Ahuja Ram (2006) A Research Methods, Jaipur: Rawat Publication.

2. Chattopadhyay, D. and Rakshit, P.C. An Advance course in Practical Physics Kolkata: New Central Book Agency(P) Ltd.

3. E., Balagurusamy, Numerical Methods, Tata Mc. Graw Hill.

4. Jain M.K., and Iyengar, Numerical methods problems and solutions, New Age International Ltd.

5. Kothari, C.R. (1989) Research Methodology: Methods and Techniques, Bangalore: Wiley Eastern.

6. Rosander, A.C.(1965) Elements of Probability and Principles of Statistics, Calcutta: East West Press.

7. Scarborough J.B., (1971) Numerical Mathematical Analysis, New Delhi: Oxford & IBH Pub. Co.

Additional/Advance/Further Readings:

1. Allen, R.G.D.(1958) Statistics for Economics, London: Allen & Unwin.

2. Agarwal, J.C. (1989) Educational Research – An Introduction, New Delhi: Arya Book Depot.

3. Anderson T.W. An Introduction to Multivariate Statistical Analysis, New Delhi: Wiley Eastern Publication Ltd.

4. Bernad Oste and Mensing R.W. (1975) Statistics in Research Ames: The Lowa State University Press.

Course Title: General Physics Lab – 2

Course Code	PHY82DC20304	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	II	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to

1. enhance the understanding of the students of procedural knowledge of condensed matter physics.
2. enhance the ability of the students to explain the processes and applications related to condensed Matter physics.
3. develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. develop interest and motivate the master students towards experiment research.
5. enhance the scientific understanding of advanced instruments which will help them for research.
6. develop ability to work together.
7. develop an ability to express themselves coherently and logically.
8. develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Comprehend the concepts through experiments.
2. express the basic concepts of Condensed Matter physics in more general language.
3. Design and develop the instruments for advanced studies.
4. Evaluate theoretical calculations using experimental observations.

5. Having a clear understanding of the subject related concepts and of contemporary issues.
6. Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

Course Contents:

1. G M Tube Counter
2. Differential Amplifier
3. Monte Carlo integration
4. Use of a package for data generation and graph plotting.
5. Test of randomness for random numbers generators
6. Hall Effect
7. Experimental set-up for study of Kerr effect and measurement of Kerr constant using Halogen light source
8. Transmission Line Experiment
9. Linear curve fitting and calculation of linear correlation coefficient
10. IC 555 Timer
11. Polarization of light using Half-Wave Plate
12. Experimental set-up for measurement of permeability and permittivity of air
13. e/m Experiment by Thomson's method
14. Lattice dynamics mono atomic and diatomic
15. Metal oxide semiconductor Field effect transistor (MOFET)
16. Channel function arbitrary waveform Generator & Digital storage Oscilloscopes & UPS
17. Romtek Fiber Optics trainer model 7140

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Classical Electrodynamics

Course Code	PHY82DE20402	**Credits**	2
L+T+P	2+0+0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	30(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. To understand how materials are affected by electric and magnetic fields.
2. To understand the relation between the fields under time varying situations and also the Maxwell equations.
3. To understand principles of propagation of uniform plane waves.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Recall the concepts of electrostatics for different charge distribution systems.
2. Comprehend the basics of magnetostatics and their applications to understand the concepts of magnetism in magnetic materials.
3. Demonstrate the knowledge of electricity and magnetism to derive Maxwell's equations and be able to apply them to real electromagnetic systems.
4. Derive the electromagnetic wave equations from Maxwell's equations and calculate the energy carried by electromagnetic waves.
5. Analyze the propagation of electromagnetic waves and the phenomena of reflection, refraction, transmission of these waves in different mediums.
6. Realise the concepts of waveguides/transmission lines and modes of electromagnetic waves.
7. Develop understanding of dynamics of charges in electromagnetic fields and generation of electromagnetic radiations from moving charge systems such as dipole.

Course Contents:

Unit-1:Electromagnetic Theory

Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems, the Method of Images, Separation of Variables and Multipole Expansion. Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces.

(15 % Weightage)

Unit-2:Electrodynamics

Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations. Scalar and vector potentials, gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics.

(15 % Weightage)

Unit-3: Electromagnetic waves

Electromagnetic waves in non conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reflection and transmission at interfaces. Fresnel's laws, interference, coherence transmission line and wave guides; Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion: Dispersion in non conductors, free electrons in conductors and plasmas. Guided waves.

(40 % Weightage)

Unit-4:Electromagnetic Radiation

Retarded potentials, Electric dipole radiation, magnetic dipole radiation. Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion, Power radiated by a point charge.

(40 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-3	Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems, the Method of Images, Separation of Variables and Multipole Expansion.
4-6	Magnetostatics: Biot-Savart law, Ampere's theorem. Electromagnetic induction. Maxwell's equations in free space and linear isotropic media; boundary conditions on the fields at interfaces.
7-9	Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations. Scalar and vector potentials,
10-12	gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics.,
13-16	Electromagnetic waves in non conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reflection and transmission at interfaces.

17-20	Fresnel's laws, interference, coherence transmission line and wave guides; Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion,
21-22	Dispersion in non conductors, free electrons in conductors and plasmas. Guided waves.
23-28	Retarded potentials, Electric dipole radiation, magnetic dipole radiation, Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion.
28-30	Power radiated by a point charge.

Essential Readings:

1. Introduction to Electrodynamics, D. J. Griffith, 4th edition, Addison-Wesley Professional, Boston,2012.
2. Foundations of Electromagnetic Theory, J.R. Reitz., F.J. Milford and R. W. Christy, 2010, 4th edition, Pearson.

Additional/Advance/Further Readings:

1. Classical Electrodynamics, J.D. Jackson, 3rd edition, Wiley-India, Delhi, 2011.
2. Classical Electrodynamics, W. Greiner, 3rd edition, Springer, New York, 2010.

Course Title: Nuclear and Particle Physics

Course Code	PHY82DE20502	**Credits**	2
L+T+P	2+0+0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	30(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group Discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to introduce students to the fundamental concepts of nuclear and sub-nuclear physics. Starting with an overview of the development of nuclear and particle physics, the course builds on previous learning in quantum mechanics and electromagnetism to develop students' understanding of the properties of the strong and weak forces. Topics covered include the experimental apparatus needed to study

1. To introduce properties of nuclei and details of popular nuclear models.
2. To derive and discuss properties of nuclear decays and nuclear reactions in brief.
3. To familiarize with the fundamental forces and the dynamics of elementary particles under these forces.
4. To overview basic relativistic quantum mechanics and quantum electrodynamics for particle physics.

Course Learning Outcomes:

1. Understand the fundamental principles and concepts governing classical nuclear and particle physics and have a working knowledge of their application to real-life problems.
2. Demonstrate knowledge and understanding of scientific phenomena, facts, laws, definitions, concepts, theories, scientific vocabulary, terminology, conventions, scientific quantities and their determination, order-of-magnitude estimates, scientific and technological applications as well as their social, economic and environmental implications.
3. Demonstrate comprehension of physical reality through estimation, approximation, and mathematical modeling, and understand how a small number fundamental physical principles underlie a huge variety of interconnected natural phenomena.
4. Describe basic properties of nuclei, nuclear interactions, nuclear structure and reactions.
5. Identify the strengths and limitations of various nuclear models.
6. Relate theoretical predictions and measurements of Quantum mechanical reasoning in classification of processes in subatomic world .

7. Apply the knowledge of basic laws of conservation and momentum in the determination of particle properties and properties of processes in the subatomic world.

8. Work on elementary problem solving in nuclear and particle physics, and relating theoretical predictions and measurement results.

9. Demonstrate the ability to critically evaluate the results in nuclear and particle physics.

Course Contents:

Unit-1

Basic Properties of the Nucleus and Their Determination, Determination of Nuclear Charge, Determination of Nuclear Mass, Determination of Nuclear Radius, Nuclear Angular Momentum, Magnetic Dipole Moment, and Electric Quadrupole Moment, Determination of Nuclear Angular Momentum, Determination of Nuclear Magnetic Moment, Determination of the Nuclear Quadrupole Moment Q. Radioactive Decay: Radioactive Series, Elementary ideas of alpha, beta and gamma decays and their selection rules. Non-conservation of Parity in a Decay. (25 % Weightage)

Unit-2

Nuclear models: Liquid drop model, Weizsacker's Semi-empirical mass or binding energy formula; Shell model: Evidence for magic numbers, prediction of energy levels in an infinite square well potential, spin-orbit interaction, prediction of ground state spin, parity of nucleus; Collective models of the Nucleus. (25 % Weightage)

Unit-3

Quantities Conserved in a Nuclear Reaction, Quantities that are not Conserved in Nuclear Reactions, The Q Equation, The Partial Wave Analysis of Nuclear Reaction Cross-section, Reaction Mechanism, Test of the Compound Reaction Mechanism: Excitation Functions and Ghoshal's Experiment, Pre-equilibrium (or Pre-compound) Emission in Statistical Nuclear Reactions, Heavy Ion (HI) Reactions, Optical Model Approach to Nuclear Reactions. (25 % Weightage)

Unit-4

Particle Physics : Review of types of interaction in nature-typical strengths and time-scales, laws of conservation: charge-conjugation, parity and time reversal, CPT theorem and its implications, GellMann-Nishijima formula, intrinsic parity of pions, resonances, symmetry classification of elementary particles, quark hypothesis, charm, beauty and truth, gluons, quark confinement, asymptotic freedom.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-7	**Unit-1**
1-2	Basic Properties of the Nucleus and Their Determination, Determination of Nuclear Charge,
2-3	Determination of Nuclear Mass, Determination of Nuclear Radius, Nuclear Angular Momentum
3-4	Magnetic Dipole Moment, and Electric Quadrupole Moment, Determination of Nuclear Angular Momentum,

4-5	Determination of Nuclear Magnetic Moment, Determination of the Nuclear Quadrupole Moment Q.
6-7	Radioactive Decay: Radioactive Series, Elementary ideas of alpha Radioactive Decay: Radioactive Series, Elementary ideas of alpha, beta and gamma decays their selection rules. Non-conservation of Parity in a Decay.
7-14	**Unit-2**
7-8	Liquid drop model, Weizsacker's Semi-empirical mass or binding energy formula
8-9	Shell model: Evidence for magic numbers, prediction of energy levels in an infinite square well potential
9-10	spin-orbit interaction
10-11	prediction of ground state spi
11-12	parity of nucleus
13-14	Collective models of the Nucleus
14-21	**Unit-3**
14-15	Quantities Conserved in a Nuclear Reaction
15-16	Quantities that are not Conserved in Nuclear Reactions
16-17	The Partial Wave Analysis of Nuclear Reaction Cross-section, Reaction Mechanism,
18-19	Ghoshal's Experiment, Pre-equilibrium
10-20	Emission in Statistical Nuclear Reactions
20-21	Heavy Ion (HI) Reactions, Optical Model Approach to Nuclear Reactions
21-30	**Unit-4**
21-22	Review of types of interaction in nature-typical strengths and time-scales
23-24	laws of conservation: charge-conjugation, parity and time reversal
25-25	CPT theorem and its implications
25-26	GellMann-Nishijima formula, intrinsic parity of pions, resonances
27-28	symmetry classification of elementary particles
28-29	quark model, gluons, quark confinement
29-30	asymptotic freedom.

Essential Readings:

1. Nuclear Physics by V. Devanathan. Narosa Publishing House, Delhi.
2. Nuclear Physics, R. Prasad, Pearson.
3. Introduction to Nuclear Physics, Kenneth Krane, Wiley India Pvt. Ltd.
4. Introduction to Nuclear Physics, H. A. Enge, Eddison Wesley
5. Nuclei and Particle, E. Segre, W. A Benjamin,
6. Concepts of Nuclear Physics, B. L. Cohen

Additional/Advance/Further Readings:

1. Nuclear and Particle Physics, W. E. Burcham and M. Jobes, Addison Wesley
2. Nuclear Structure Vol. 1 & 2., Aaghe Bohr & Ben R. Mottelson, World Scientific.
3. Fundamentals In Nuclear Physics, Jean-Louis Basdevant, James Rich, Michel Spiro, Springer.

4. Introductory Nuclear Physics, Samuel S. M. Wong, Wiley-Vch.
5. Source Book on Atomic Energy, Samuel Glasstone, Litton Educational Publishing.

Course Title: Solid State Physics

Course Code	PHY82DE20602	**Credits**	2
L+T+P	2+0+0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	30(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce the concept of crystallography, structural aspects of materials, different properties of solids and their structure property correlation, and develop the framework and analytical skills necessary to understand these phenomena in nature. This course aims are

1. Students will be able to learn basics of solid state Physics.
2. Students will be able to correlate its applications in the area of advanced condensed matter physics.
3. Students will develop an ability to understand and assimilate higher level topics by themselves.
4. The student will learn the basics understanding of structure and different phenomenon of sold state physics.
5. This course should give the student confidence to undertake higher level education or job assignments in various institutes in India or in abroad.

Course Learning Outcomes:

After completion of the course learners will be able to:

1. Understand the fundamentals of atomic arrangements in solids.
2. Realize basic symmetry elements and how these symmetry operations are important in solid sate physics.
3. Understand basic concept crystallography .
4. Understand the arrangements of solid and visualize different important structures of solids.
5. understand the basics of diffraction phenomenon lattice planes and information contained in the X-Ray diffraction data.
6. understand basics phenomenon and their theory of solids
7. understand Electrical, dielectric , magnetic, superconducting properties and their theory.
8. understand structure property correlation.

Course Contents:

Unit-1

Crystal structure: Periodic arrangement of atoms-lattice translation vectors, The basis and crystal structure, primitive and non-primitive lattice cell-fundamental types of lattice, -2d and 3-d Bravias lattice and crystal systems. Elements of symmetry operations points and space groups-nomenclature of crystal directions and crystal planes-miller indices,Bonding of solids, Defects and dislocations, Quasi crystals. Super-fluidity. Ordered phases of matter: transnational and orientation order, kinds of liquid crystalline order. X-ray diffraction: Scattering of x-rays, Laue conditions and Bragg's law, atomic scattering factor, geometrical structure factor, Reciprocal lattice and its properties.

(50 % Weightage)

Unit-2

roperties of Solids: Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat. Response and relaxation phenomena.Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, Introduction to band theory of solids: metals, insulators, Elementary ideas of quantum Hall effect, Cyclotron resonance and magnetoresistance, Introduction to superconductivity.Josephson junctions.

(50 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Periodic arrangement of atoms-lattice translation vectors, The basis and crystal structure, lattice cell-fundamental types of lattice, -2d and 3-d Bravias lattice and crystal systems.
5-8	Elements of symmetry operations points and space groups-nomenclature of crystal directions and crystal planes-miller indices,Bonding of solids,
9-12	Defects and dislocations, Quasi crystals. Superfluidity. Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order
13-16	Scattering of x-rays, Laue conditions and Bragg's law, atomic scattering factor, geometrical structure factor, Reciprocal lattice and its properties.
17-20	Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat.
21-24	Response and relaxation phenomena.Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power
25-28	Electron motion in a periodic potential, Introduction to band theory of solids: metals, insulators
28-30	Elementary ideas of quantum Hall effect, Cyclotron resonance and magnetoresistance, Introduction to superconductivity.Josephson junctions.

Essential Readings:

1. Solid State Physics- A. J. Dekker.

2. Elementary Solid state physics,- M.A. Omar

3. Introduction of Solids: L.V. Azaroff.
4. Solid State Physics: N.W. Ashcroft and N.D. Mermin
5. Solid State Physics by S.O.Pillai

Additional/Advance/Further Readings:

1. Solid State Physics- C. Kittel.
2. Crystallography by Verama Srivastava.

Course Title: Indian Knowledge Systems in modern context

Course Code	PHY82ME20800	**Credits**	Non-credit Mandatory
L+T+P	Non-credit Mandatory	**Course Duration**	One Semester
Semester	II	**Contact Hours**	30(L) Hours

Course Type	Mandatory Elective Non-credit Course
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Value Addition, Indian Knowledge Systems
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	Attendance / Group discussion / Presentation / Viva etc.

Course Objectives:

The main objective of this course is to make students understand the importance and utility of different ideas in Indian Knowledge Systems in todays world.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. appreciate the importance of different traditions in indian knowledge systems.
2. apply different ideas of indian knowledge systems in daily life activities.
3. utilise these concepts to develop further ideas with potential to get implemented in modern world.

Course Contents:

Indian Knowledge Systems - Very old yet always new; Vedantic understanding of the number system and its implications in modern physics; Ganita and Modern Mathematics; Shaastra and Modern Science; Pramaana (Pratyaksha, Anumaana and Shabda) & Lokapramaana in view of modern statistical studies/clinical trials etc.; Hetvaabhaasa and and its relevance in policy making for Indian science; Discussion on modern concept of patent/copyright in view of ancient practices; Sanskrit for technical discourse; Pandemics in ancient scientific literature, Teeka in India in contrast to the modern vaccines; Comparative study of modern economic system with the ancient one; Indian systems as a solution to environmental problems, Trees and livestock as energy source; Modern day experiments based on Indian Knowledge Systems in agriculture; Indian knowledge systems for solutions to the existing world health problems; The Ancient Indian Education System in contrast to the modern day education system; Analysis of traditional indian dresses in modern context; Role and status of women in Indian systems.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1	Indian Knowledge Systems - Very old yet always new

2-6	Vedantic understanding of the number system and its implications in modern physics; Ganita and Modern Mathematics; Shaastra and Modern Science
7-10	Pramaana (Pratyaksha, Anumaana and Shabda) & Lokapramaana in view of modern statistical studies/clinical trials etc.
11-13	Hetvaabhaasa and and its relevance in policy making for Indian science; Discussion on modern concept of patent/copyright in view of ancient practices; Sanskrit for technical discourse
14-17	Pandemics in ancient scientific literature, Teeka in India in contrast to the modern vaccines
18-22	Comparative study of modern economic system with the ancient one
23-25	Indian systems as a solution to environmental problems, Trees and livestock as energy source; Modern day experiments based on Indian Knowledge Systems in agriculture; Indian knowledge systems for solutions to the existing world health problems
26-28	The Ancient Indian Education System in contrast to the modern day education system
29-30	Analysis of traditional indian dresses in modern context; Role and status of women in Indian systems.

Essential Readings:

1. Indian Science and Technology in the Eighteenth Century: Some Contemporary European Accounts - Dharampal

2. The Wonder that is Sanskrit - Sampad & Vijay; Auro Publications

3. Sanskrit Non-translatables: The importance of Sanskritizing English - Rajiv Malhotra & Satyanaranaya Dasa Babaji

Additional/Advance/Further Readings:

1. Different ancient indian texts

Course Title: Condensed Matter Physics

Course Code	PHY91DC20103	**Credits**	3
L+T+P	3+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	45(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. The course is to give a broad phenomenological overview and background to cutting-edge topics of modern condensed matter physics.
2. Students will learn the advanced topics in solid state theory to apply in materials science research.
3. The goal is to address many-body effects in solid state systems.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Understand the electronic states govern the material properties microscopically.
2. Learn the free-electron metallic states as the simplest itinerant electron system.
3. Comprehend the electron states of solid crystals become Bloch states.
4. Apply many-body effects among electrons reduce the Coulomb-repulsion energy.
5. Understand the basics of first-principles electron theory to describe electronic states non-empirically.
6. Demonstrate the above mentioned ideas from industrial perspective.

Course Contents:

Unit-1

Boltzmann transport equation, resistivity of metals and semiconductors, Fermi surfaces – determination, Landau levels, de Hass van Alphen effect, Quantum Hall effect- Integral quantum Hall effect and. Magnetoresistance.

(25 % Weightage)

Unit-2

Dielectrics and ferroelectrics, macroscopic electric field, local field at an atom, dielectric constant and polarizability, ferroelectricity, antiferroelectricity, piezoelectric crystals, ferroelasticity, electrostriction.

(25 % Weightage)

Unit-3

Optical constants and their physical significance, Reflectivity in metals, plasmonic properties of metals, determination of band gap in semiconductors: direct and indirect band gap, defect mediated optical transitions, excitons, photoluminescence, Electroluminesence. (25 % Weightage)

Unit-4

Types of magnetic materials, Quantum theory of paramagnetism, Hund's rule, Ferromagnetism, antiferromagnetism: molecular field, Curie temperature. Domain theory, Magnetic Anisotropy, Magnetic interactions, Heitler-London method, exchange and superexchange, magnetic moments and crystal-field effects, spin-wave excitations and thermodynamics, antiferromagnetism, Magnetostriction. (25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Boltzmann transport equation, resistivity of metals and semiconductors.
5-6	Fermi surfaces – determination, Landau levels.
7-10	de Hass van Alphen effect, Quantum Hall effect- Integral quantum Hall effect.
11-13	Magnetoresistance and Dielectrics and ferroelectrics
14-16	macroscopic electric field, local field at an atom, dielectric constant and polarizability.
17-19	ferroelectricity, antiferroelectricity
20-22	piezoelectric crystals, ferroelasticity, electrostriction.
23-24	Optical constants and their physical significance
25-27	Reflectivity in metals, plasmonic properties of metals
28-30	determination of band gap in semiconductors: direct and indirect band gap,
11-34	defect mediated optical transitions, excitons, photoluminescence
35-38	Electroluminesence, Types of magnetic materials, Quantum theory of paramagnetism,
39-41	Hund's rule, Ferromagnetism, antiferromagnetism: molecular field,
42-43	Curie temperature. Domain theory, Magnetic Anisotropy, Magnetic interactions, Heitler-London method, exchange and superexchange, magnetic moments
44-45	crystal-field effects, spin-wave excitations and thermodynamics, antiferromagnetism, Magnetostriction.

Essential Readings:

1. Introduction to Solid State Theory, Otfried Madelung, Springer (2008).

2. Solid State Physics, Giuseppe Grosso and Giuseppe Pastori Parravicini, Elsevier (2012).
3. Quantum Theory of Solids, Charles Kittel, Wiley (1987).
4. Solid State Theory, Walter A. Harrison, Dover Publications (2012).

Additional/Advance/Further Readings:

1. Advanced Solid State Theory, Thomas Pruschke, Morgan and Claypool (2014).
2. Advanced Solid State Physics, Philip Phillips, Cambridge University Press (2012).
3. Solid State Physics: Introduction to the Theory, James Patterson and Bernard Bailey, Springer (2010).
4. Many-Body Quantum Theory in Condensed Matter, Henrik Bruus and Karsten Flensberg, Oxford University Press (2005),

Course Title: Condensed Matter Physics Lab-1

Course Code	PHY91DC20204	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	III	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to

1. enhance the understanding of the students of procedural knowledge of condensed matter physics.
2. enhance the ability of the students to explain the processes and applications related to condensed Matter physics.
3. develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. develop interest and motivate the master students towards experiment research.
5. enhance the scientific understanding of advanced instruments which will help them for research.
6. develop ability to work together.
7. develop an ability to express themselves coherently and logically.
8. develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Comprehend the concepts through experiments.
2. express the basic concepts of Condensed Matter physics in more general language.
3. Design and develop the instruments for advanced studies.
4. Evaluate theoretical calculations using experimental observations.

5. Having a clear understanding of the subject related concepts and of contemporary issues.
6. Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

Course Contents:

1. To study the relationship between temperature of given samples (1&2) and its time of cooling by plotting a cooling curve and identify the samples.
2. To study Hall Effect in semiconductor and determine Hall coefficient (Rh) & charge career density.
3. To evaluate modest nano-particles concentrations in the fluid for significant enhancement of its property.
4. Study of phase transition and to detect/assess weak and strong molecular interactions in nano-fluids.
5. To determine the Stefan's constant by using an incandescent lamp and Photovoltaic cell.
6. To demonstrate Hysteresis curve of hard magnet.
7. To determine Dielectric constant of specimen at high frequency by Lecher wires.
8. To study the dispersion relation for mono-atomic lattice and determine the cut of frequency.
9. To determine heat capacity of solids
10. Measurement of Planck's constant using LED.
11. Measurement of Planck's constant using photo voltaic cell
12. Phase problem and determination of crystal structures.
13. Indexing of X-Ray powder diffraction patterns.
14. Atomic scattering factor and structure factor determination.
15. Experimental determination of space group and inversion symmetry.
16. Refinement procedures

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Experimental Techniques for Materials Science

Course Code	PHY91DE20303	**Credits**	3
L+T+P	3+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	45 (L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. To enable the students to understand the concepts of various instruments and improve their knowledge in characterization techniques for further advanced research studies.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Identify and compare state-of-the-art nanofabrication methods and perform a critical analysis of the research literature.
2. Evaluate state-of-the-art characterization methods for nanomaterials, and determine nanomaterial safety and handling methods required during characterization.
3. Apply interdisciplinary systems of engineering approaches to the field of bio and nanotechnology systems.
4. Having a clear understanding of the subject related concepts and of contemporary issues

Course Contents:

Unit-1

Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar,viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion). Digital Instruments: Principle and working of digital meters, comparison of analog and digital instruments, characteristics of a digital meter.

(33 % Weightage)

Unit-2

Diffraction Techniques: X-ray diffraction, Neutron diffraction,Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction. Microscopic Techniques: Optical Microscopy; Scanning Electron Microscopy; Scanning Tunneling Microscopy; Atomic Force Microscopy; Transmission Electron Microscopy.
(33 % Weightage)

Unit-3

Spectroscopic Techniques: Electron Spectroscopy for chemical analysis; Auger Electron spectroscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR, Raman and surface enhanced Raman Spectroscopy. X-ray Fluorescence; Rutherford back scattering; UV VIS-NIR spectro-photometer, Ellipsometry; Deep Level Transient Spectroscopy; Thermally Simulated Current; C-V and Admittance Spectroscopy; Hall effect and Time of Flight methods for charge carriers, Differential scanning calorimeter; Differential Thermal Analyzer. (34 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar,viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion).
5-8	Digital Instruments: Principle and working of digital meters, comparison of analog and digital instruments, characteristics of a digital meter.,
9-12	Diffraction Techniques: X-ray diffraction, Neutron diffraction,Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction.
13-16	Optical Microscopy; Scanning Electron Microscopy; Scanning Tunneling Microscopy; Atomic Force Microscopy; Transmission Electron Microscopy.
17-20	Spectroscopic Techniques: Electron Spectroscopy for chemical analysis; Auger Electron spectroscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR,
21-24	Raman and surface enhanced Raman Spectroscopy. X-ray Fluorescence; Rutherford back scattering; UV VIS-NIR spectro-photometer, Ellipsometry; Deep Level Transient Spectroscopy; Thermally Simulated Current;
25-30	C-V and Admittance Spectroscopy; Hall effect and Time of Flight methods for charge carriers, Differential scanning calorimeter; Differential Thermal Analyzer.

Essential Readings:

1. Sayer, M., Mansingh, A., Measurement, Instrumentation and Experiment Design in Physics and Engineering, PHI (2000).

2. Nanotechnology-Molecularly Designed Materials : G.M. Chow and K.E. Gonsalves (American Chemical Society), 1996.

Additional/Advance/Further Readings:

1. Nanoparticles and Nanostructured Films–Preparation, characterization and Application : J.H. Fendler (Wiley), 1998
2. Crystallography Applied to Solid State Physics: A.R. Verma and O.N. Srivastava.

Course Title: Solid State Devices

Course Code	PHY91DE20404	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	60(L)Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

1. The main objectives of this course are
2. To acquaint students about the basic theories of solid state structure.
3. To learn to apply the free electron theory to solid materials to describe their electronic behavior.
4. To understand the origin of energy bands and how they influence electronic behavior.
5. To learn to apply different models of solid state physics to describe the properties of solids and electronic devices.

Course Learning Outcomes:

Upon successful completion of the course, students should:

1. have an understanding of the elastic properties of solids and lattice vibrations,
2. have an understanding of the properties of metals on the basis of the free and nearly-free electron gas models,
3. have an understanding of the essence of density functional theory and its underlying building blocks,
4. have an understanding of the electrical, magnetic and superconducting properties of condensed matter;

Course Contents:

Unit-1

Classification of Semiconductors; Crystal structure with examples of Si, Ge & GaAs semiconductors; Energy band structure of Si, Ge & GaAs; Extrinsic and compensated Semiconductors; Temperature dependence of Fermi-energy and carrier concentration. Drift, diffusion and injection of carriers; Carrier generation and recombination processes- Direct recombination, Indirect recombination, Surface recombination, Auger recombination;

Applications of continuity Equation-Steady state injection from one side, Minority carriers at surface, Haynes Shockley experiment, High field effects. Hall effect; Four – point probe resistivity measurement; Carrier life time measurement by light pulse technique. Introduction to amorphous semiconductors, Growth of semiconductor crystals.

(35 % Weightage)

Unit-2

Fabrication of p-n junction by diffusion and ion-implantation; Abrupt and linearly graded junctions; Thermal equilibrium conditions; Depletion regions; Depletion capacitance, Capacitance – voltage (C-V) characteristics, Evaluation of impurity distribution, Varactor; Ideal and Practical Current-voltage (I-V) characteristics; Tunneling and avalanche reverse junction break down mechanisms; Minority carrier storage, diffusion capacitance, transient behavior; Ideality factor and carrier concentration measurements; Carrier life time measurement by reverse recovery of junction diode; p-i-n diode; Tunnel diode, Introduction to p-n junction solar cell and semiconductor laser diode.

(35 % Weightage)

Unit-3

Schottky barrier – Energy band relation, Capacitance- voltage (C-V) characteristics, Current-voltage (I-V) characteristics; Ideality factor, Barrier height and carrier concentration measurements; Ohmic contacts. Bipolar Junction Transistor (BJT): Static Characteristics; Frequency Response and Switching. Semiconductor heterojunctions, Heterojunction bipolar transistors

(15 % Weightage)

Unit-4

Junction Field Effect Transistor (JFET) - Construction, Characteristic parameters, Transfer Characteristics, applications; Introduction to ideal MOS device; MOSFET fundamentals, Measurement of mobility, channel conductance etc. from Ids vs Vds and Ids vs Vg characteristics; Metal-semiconductor field effect transistor (MESFET)- Device structure, Principles of operation, Current voltage (I-V) characteristics, High frequency performance.

(15 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Classification of Semiconductors; Crystal structure with examples of Si, Ge & GaAs semiconductors; Energy band structure of Si, Ge & GaAs; Extrinsic and compensated Semiconductors;
5-8	Temperature dependence of Fermi-energy and carrier concentration. Drift, diffusion and injection of carriers; Carrier generation and recombination processes- Direct recombination,
9-12	Indirect recombination, Surface recombination, Auger recombination; Applications of continuity Equation-Steady state injection from one side, Minority carriers at surface, Haynes Shockley experiment, High field effects.
13-16	Hall effect; Four – point probe resistivity measurement; Carrier life time measurement by light pulse technique. Introduction to amorphous semiconductors, Growth of semiconductor crystals.

17-20	Fabrication of p-n junction by diffusion and ion-implantation; Abrupt and linearly graded junctions; Thermal equilibrium conditions; Depletion regions; Depletion capacitance, Capacitance – voltage (C-V) characteristics, Evaluation of impurity distribution, Varactor;
21-24	Ideal and Practical Current-voltage (I-V) characteristics; Tunneling and avalanche reverse junction break down mechanisms; Minority carrier storage, diffusion capacitance, transient behavior;
25-28	Ideality factor and carrier concentration measurements; Carrier life time measurement by reverse recovery of junction diode; p-i-n diode;
28-32	Tunnel diode, Introduction to p-n junction solar cell and semiconductor laser diode.
32-36	Schottky barrier – Energy band relation, Capacitance- voltage (C-V) characteristics, Current-voltage (I-V) characteristics;
36-40	Ideality factor, Barrier height and carrier concentration measurements; Ohmic contacts. Bipolar Junction Transistor (BJT): Static Characteristics;
41-44	Frequency Response and Switching. Semiconductor heterojunctions, Heterojunction bipolar transistors
45-48	Junction Field Effect Transistor (JFET) - Construction, Characteristic parameters, Transfer Characteristics, applications;
49-52	Introduction to ideal MOS device; MOSFET fundamentals, Measurement of mobility, channel conductance etc. from Ids vs Vds and Ids vs Vg characteristics;
53-56	Metal-semiconductor field effect transistor (MESFET)- Device structure,
57-60	Principles of operation, Current voltage (I-V) characteristics, High frequency performance

Essential Readings:

1. S.M. Sze; Semiconductor Devices: Physics and Technology, 2nd edition, John Wiley, New York, 2002.

2. B.G. Streetman and S. Benerjee; Solid State Electronic Devices, 5th edition, Prentice Hall of India, NJ, 2000.

3. W.R. Runyan; Semiconductor Measurements and Instrumentation, McGraw Hill, Tokyo, 1975.

Additional/Advance/Further Readings:

1. Adir Bar-Lev: Semiconductors and Electronic devices, 2nd edition, Prentice Hall, 1984.

2. Donald A. Neamen; Semiconductor Physics and Devices: Basic Principles, 3rd edition, Tata McGraw-Hill, New Delhi, 2002.

3. M. Shur; Physics of Semiconductor Devices, Prentice Hall of India, New Delhi, 1995.

4. Integrated Electronics by Jacob Millman, Christos Halkias, Tata McGraw-Hill Education Private Limited, 2009

Course Title: Advanced Condensed Matter Physics

Course Code	PHY92DC20104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. The course is to give a broad phenomenological overview and background to cutting-edge topics of modern condensed matter physics.
2. Students will learn the advanced topics in solid state theory to apply in materials science research.
3. The goal is to address many-body effects in solid state systems.
4. To know the basic science of magnetism and visualize the applications.
5. To understand the theory of magnetization dynamics and the necessity magnetic anisotropy.
6.
7.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Understand the electronic states govern the material properties microscopically.
2. Learn the free-electron metallic states as the simplest itinerant electron system.
3. Comprehend the electron states of solid crystals become Bloch states.
4. Apply many-body effects among electrons reduce the Coulomb-repulsion energy.
5. Understand the basics of first-principles electron theory to describe electronic states non-empirically.
6. Demonstrate the above mentioned ideas from industrial perspective.
7. Explain the fundamentals of magnetism by molecular field theory and band theory.

8. Apply solid state physics to appreciate domain wall mechanism.
9. Analyze the magnetization dynamics through various characterization techniques.
10. Interpret the physical origin of magnetic anisotropy and its effects.
11. Evaluate the magnetostriction for various single and polycrystalline materials.
12. Recall the mechanism of Magnetocalorics and Magnetoelectronics.

Course Contents:

Unit-1: Magnetic properties of solids

Diamagnetism, Paramagnetism of atoms with permanent magnetic moment, Pauli paramagnetism of conduction electrons, magnetic exchange interaction, Heisenberg model for ferro and antiferromagnetic insulators, magnons in ferro and antiferro-magnets, magnon contribution to specific heat, Stoner theory of ferro-magnetism of itinerant electrons (brief), second quantization (brief), local moment formation in metals, brief discussion of Kondo effect and Heavy fermion systems.

(40 % Weightage)

Unit-2:Superconductivity

Phenomenological theories of superconductivity, Meissner effect, thermodynamics of superconductors, London's phenomenological theory, flux quantization, Copper instability, BCS theory of superconductivity, Coulomb pseudo-potential, strong coupling effects, Josephson effects, High temperature superconductors – applications, Ginzburg-Landau theory.

(20 % Weightage)

Unit-3:Special topics

Integral and fractional quantum Hall effect: electron in a strong magnetic field, Landau levels and their degeneracy, simple explanation of IQHE; Metal-Insulator transitions: Mott- Hubbard and impurity induced; Landau theory of Fermi liquid, Mott variable range hopping, Bose- Einstein condensation. Introduction of cryogenic systems

(40 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Diamagnetism, Paramagnetism of atoms with permanent magnetic moment
5-8	Pauli paramagnetism of conduction electrons, magnetic exchange interaction,
9-15	Heisenberg model for ferro and antiferromagnetic insulators, magnons in ferro and antiferro-magnets, magnon contribution to specific heat,
16-20	Stoner theory of ferro-magnetism of itinerant electrons (brief), second quantization (brief), local moment formation in metals, brief discussion of Kondo effect and Heavy fermion systems.
21-24	Phenomenological theories of superconductivity, Meissner effect, thermodynamics of superconductors, London's phenomenological theory, flux quantization, Copper instability,
25-28	BCS theory of superconductivity, Coulomb pseudo-potential, strong coupling effects, Josephson effects,

28-32	High temperature superconductors – applications, Ginzburg- Landau theory.
32-36	Integral and fractional quantum Hall effect: electron in a strong magnetic field, Landau levels and their degeneracy,
36-44	simple explanation of IQHE; Metal-Insulator transitions: Mott- Hubbard and impurity induced; Landau theory of Fermi liquid,
45-50	Mott variable range hopping, Bose- Einstein condensation.
51-60	Introduction of cryogenic systems

Essential Readings:

1. Introduction to Solid State Theory, Otfried Madelung, Springer (2008).
2. Solid State Physics, Giuseppe Grosso and Giuseppe Pastori Parravicini, Elsevier (2012).
3. Quantum Theory of Solids, Charles Kittel, Wiley (1987).
4. Solid State Theory, Walter A. Harrison, Dover Publications (2012).
5. Jiles David, Introduction to magnetism and magnetic materials,3rd edition, 2015, London: Chapman & Hall.
6. K.H. J. Buschow, Handbook of Magnetic Materials, 1 edition, 2014, North Holland Publisher.

Additional/Advance/Further Readings:

1. Advanced Solid State Theory, Thomas Pruschke, Morgan and Claypool (2014).
2. Advanced Solid State Physics, Philip Phillips, Cambridge University Press (2012).
3. Solid State Physics: Introduction to the Theory, James Patterson and Bernard Bailey, Springer (2010).
4. Many-Body Quantum Theory in Condensed Matter, Henrik Bruus and Karsten Flensberg, Oxford University Press (2005).
5. Allan H Morrish, The Physical Principle of Magnetism, 2001, willey- IEEE press.
6. D. H. Martin, Magnetism is Solids, 1967, The MIT press Ltd

Course Title: Condensed Matter Physics Lab-2

Course Code	PHY92DC20204	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to

1. enhance the understanding of the students of procedural knowledge of condensed matter physics.
2. enhance the ability of the students to explain the processes and applications related to condensed Matter physics.
3. develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. develop interest and motivate the master students towards experiment research.
5. enhance the scientific understanding of advanced instruments which will help them for research.
6. develop ability to work together.
7. develop an ability to express themselves coherently and logically.
8. develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. Comprehend the concepts through experiments.
2. express the basic concepts of Condensed Matter physics in more general language.
3. Design and develop the instruments for advanced studies.
4. Evaluate theoretical calculations using experimental observations.

5. Having a clear understanding of the subject related concepts and of contemporary issues.
6. Having computational thinking (Ability to translate vast data into abstract concepts and to understand database reasoning)

Course Contents:

1. To study characteristics of a solar cell.
2. To measure the charge Q on a plate capacitor as a function of the applied voltage E.
3. To determine the capacitance C as a function of areas A of plates.
4. To determine the capacitance C with different dielectrics between the plates.
5. To determine the capacitance C as a function of the distances d between the plates.
6. To determine resistivity of a given semiconductor by Four probe.
7. To determine the Band gap in a semiconductor using a junction diode.
8. To study Hall effect in semiconductor and determine Hall coefficient (Rh), mobility ,Hall angle tan (θ) & conductivity .
9. Crystallographic measurements using XRD.

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Advance Nuclear Physics

Course Code	PHY91DC21104	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This main objective of this course to provide the deep understanding of nuclear phenomena. Starting with an overview of the development of nuclear and particle physics, the course builds on previous learning in quantum mechanics and electromagnetism to develop student's understanding of the properties of the nucleus. This course aims to

1. impart knowledge of nuclear models and all types of radioactivity.
2. intoduce with nuclear two-body problem.
3. acquaint the students with a understanding of the role of nuclear physics in the astrophysics modeling
4. familiarize the student with the experimental set-ups and current nuclear physics research

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. describe the nuclear forces and nuclear properties.
2. explain the deuteron behavior at ground and excited states.
3. apply deuteron physics and the Nucleon-Nucleon scattering for explaining the nuclear forces.
4. demonstration of the shell model and collective model descriptions.
5. apply various aspects of nuclear reactions in view of compound nuclear dynamics
6. understand about the nuclear model like; Fermi gas model, Liquid drop model, Shell Model, Single particle shell model, Magic numbers, Collective nuclear model.
7. able to describe about the radioactive decays like α-particle emission, beta decays and gamma decay.
8. explain the Internal conversion, Nuclear isomerism.
9. understand about the nuclear reactions and their properties.
10. work on elementary problem solving in nuclear, and relating theoretical predictions and measurement results.

Course Contents:

Unit-1

Nuclear Two-Body Problem : Binding Energy of Deuteron, Ground State of Deuteron, Excited States of Deuteron, Root Mean Square Radius, Inclusion of Hard Core Potential in the Square Well, Magnetic Dipole Moment of Deuteron, Tensor Force, Quadrupole Moment, Nucleon-Nucleon Interaction: Two nucleon scattering, n-p scattering, partial wave analysis, phase-shift, scattering length, p-p scattering (qualitative discussion)

(25 % Weightage)

Unit-2

Liquid Drop Model : Semi-Empirical Mass Formula, Nuclear Instability Against Alpha Decay, β Emission, Neutron Decay, Fission and Fusion, Defects of Liquid Drop Model, Criticism of Liquid Drop Model. Fermi Gas Model: Fermi Energy, Asymmetric Term in the Mass Formula, Odd-Even Term in the Mass Formula, Threshold for Particle Production in Complex Nuclei, Application to Neutron Stars, Energy Levels of Individual Nucleons, Shell Model: Magic Numbers, LS Coupling, Predictions of the Shell Model, Magnetic Moments, Schmidt Lines, Parity of Nuclei, Nuclear Isomerism , Criticism of the Shell Model. Collective Model or Unified Model : Rotational States, Vibrational States, Electric Quadrupole Moments, General Theory of Deformed Nuclei, Rotational Model Vibrational Model, Collective Oscillations, Giant Resonances, Nilsson Model,

(25 % Weightage)

Unit-3

Nuclear Reactions: Types of Reactions, Energy and Mass Balance, Conservation Laws for Nuclear Reactions, Cross-Sections, Exoergic and Endoergic Reactions, Behaviour of Cross-Sections near Threshold, Inverse Reaction, Qualitative Features of Nuclear Reactions, Reaction Mechanisms Nuclear Reactions via Compound Nucleus Formation Partial Wave Analysis of Nuclear Reactions, Slow Neutron Resonances and the Breit-Wigner Theory, Optical Model, Direct Reactions, Inelastic Scattering, Charge-Exchange Reactions, Nucleon Transfer Reactions, Break-upReactions, Knock-out Reactions, Heavy-Ion Reactions, Characteristics of Heavy Ion Reactions, Types of Interactions, Distant Collisions, Deep Inelastic Collisions, Quark-Gluon Plasma. (25 % Weightage)

Unit-4

Nuclear Astrophysics: Brief Overview of Stellar Evolution, Big-bang nucleosynthesis, Stellar nucleosynthesis, Rate for Nonresonant Reaction, Conversion of Proton into Helium, Solar Neutrino Problem, Helium Burning and Beyond, Supernova and Synthesis of Heavy Nuclei. (25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Binding Energy of Deuteron, Ground and Excited States of Deuteron State, Root Mean Square Radius
5-8	Inclusion of Hard Core Potential in the Square Well, Magnetic Dipole Moment of Deuteron, Tensor Force, Quadrupole Moment,
9-12	Nucleon-Nucleon Interaction
13-16	Liquid Drop Model, Fermi Gas Model
17-20	Shell Model, Collective Model
21-24	General Theory of Deformed Nuclei, Giant Resonances, Nilsson Model
25-28	Types of Reactions, Energy and Mass Balance, Conservation Laws for Nuclear Reactions

28-32	Cross-Sections, Exoergic and Endoergic Reactions, Behaviour of Cross-Sections near Threshold, Inverse Reaction, Qualitative Features of Nuclear Reactions
32-36	Reaction Mechanisms, Partial Wave Analysis of Nuclear Reactions, Slow Neutron Resonances and the Breit-Wigner Theory, Optical Model, Direct Reactions, Inelastic Scattering,
36-40	Charge-Exchange Reactions, Nucleon Transfer Reactions, Break-upReactions, Knock-out Reactions, Heavy-Ion Reactions,
41-44	Characteristics of Heavy Ion Reactions, Types of Interactions, Distant Collisions, Deep Inelastic Collisions, Quark-Gluon Plasma
45-48	Brief Overview of Stellar Evolution, Big-bang nucleosynthesis
49-52	Stellar nucleosynthesis, Rate for Nonresonant Reaction, Conversion of Proton into Helium
53-56	Solar Neutrino Problem, Helium Burning and Beyond
57-60	Supernova and Synthesis of Heavy Nuclei.

Essential Readings:

1. Nuclear Physics, Anwar Kamal, Springer Berlin, Heidelberg
2. Introductory Nuclear Physics, Samuel S.M. Wong, Second Edition, Wiley-VCH Verlag GmbH & Co. KaGaA
3. Introduction to Nuclear Physics, Kenneth Krane, Wiley India Pvt. Ltd.
4. Introduction to Nuclear and Particle Physics, A. Das & T. Ferbel, World Scientific
5. Concepts of Nuclear Physics, B. L. Cohen
6. Nuclear physics in a nutshell, Carlos A Bertulani, Princeton, N.J. : Princeton University Press, 2007.

Additional/Advance/Further Readings:

1. Introduction to Nuclear Physics, Kenneth Krane, Wiley India Pvt. Ltd.
2. Introduction to Nuclear Physics, H. A. Enge, Eddison Wesley
3. Nuclei and Particle, E. Segre, W. A Benjamin,
4. Nuclear Physics, Experimental and Theoritical, H. S. Hans, New Age International
5. Introduction to Nuclear and Particle Physics, A. Das & T. Ferbel, World Scientific
6. Nuclear and Particle Physics, W. E. Burcham and M. Jobes, Addison Wesley
7. Nuclear Physics, S. N. Ghoshal, Nuclear Physics-D. C. Tayal
8. Nuclear Physics-An Introduction, S. B. Patel, New Age International

Course Title: Nuclear and Particle Physics Lab. – I

Course Code	PHY91DC21204	Credits	4
L+T+P	0+0+4	Course Duration	One Semester
Semester	III	Contact Hours	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to

1. enhance the understanding of the students of procedural knowledge of nuclear physics.
2. enhance the ability of the students to explain the processes and applications related to nuclear and particle physics.
3. develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. develop interest and motivate the master students towards experiment reserach.
5. enhance the scientific understanding of radiation safety.
6. develop ability to work together.
7. develop an ability to express themselves coherently and logically.
8. develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. handle the sophisticated detectors.
2. express the basic concepts of nuclear physics in more general language.
3. express the radioactive decays.
4. express the types of gamma decay.

5. list the types of beta decays and can express reaction equations and related Q values and enegy of beta particles.
6. demonstrate knowledge of personal radiation safety
7. Demonstrate appropriate data analysis skills.

Course Contents:

1. Study of the Characteristics of a G. M. Counters – characteristics, dead-time and counting statistics
2. Verification of Inverse square Law for Gamma-rays.
3. Esitmation of efficiency of the G.M. detector for Gamma and Beta source.
4. To Study Beta particle range and maximum energy.
5. Study of energy resolution characteristics of a scintillation spectrometer as a function of applied high voltage and to determine the best operating voltage.
6. Study of Cs-137 spectrum and calculation of FWHM & resolution for a given scintillation detector.
7. NaI(Tl) – Calibration and characteristic study, resolution and determination of gamma ray energy
8. Study of Co-60 spectrum and calculation of resolution of detector in term of energy.
9. Identification of unknown gamma ray source using known gamma emitter sources with the help of NaI(Tl) detector.
10. Setup the coincidence circuit in the a cosmic muon test bench and measure the cosmic ray muon flux in side and outdie the building.
11. Angular correlation ratio using NaI(Tl) detector.
12. Design the simple geometry of give detector setup and visualize in Geant4.
13. Absorption of γ-rays - Determination of the Half-value Thickness of Absorber Materials (Pb, Al, Fe)

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Introduction of Astroparticle Physics

Course Code	PHY91DE21304	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	III	Contact Hours	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce the students to the assorted phenomena in the field Astroparticle Physics, and develop the framework and analytical skills necessary to understand these phenomena in nature. This course aims to

1. acquaint the students with basic knowledge of the Universe outside the Solar System.
2. introduce nucleosynthesis in star
3. familiarize the student with Hertzsprung–Russell Diagram.
4. acquaint the students with the theory of the birth of cosmic-ray.
5. orient the student with the current status of the high energy neutrino and gamma-ray astronomy.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. understand the fundamentals in the Astrophysics.
2. describe the basic equations of stellar structure.
3. describe Hertzsprung–Russell Diagram.
4. understand the basic concepts of helioseismology and solar neutrino experiments.
5. describe the Ultra High Energy Cosmic Ray (UHECR) interactions on the microwave background.
6. comprehend the GZK cutoff, current status of the field.
7. identify their area of interest.

Course Contents:

Unit-1

Basic equations of stellar structure: Hydrostatic equilibrium in stars, Virial theorem for stars, Energy transport inside stars, Convection inside stars; Constructing stellar models, stellar observational data, Main sequence, red giants and white dwarfs, Eddington luminosity limit, HR diagrams of star clusters.

(25 % Weightage)

Unit-2

Nucleosynthesis: The possibility of nuclear reactions in stars, Calculation of nuclear reaction rates, Important nuclear reactions in stellar interiors, stellar models and experimental confirmation: Helioseismology, Solar neutrino experiments; Stellar evolution, Evolution in binary systems, Mass loss from stars, Stellar winds, Degeneracy pressure of a Fermi gas, Structure of white dwarfs, Chandrasekhar mass limit, Supernovae, The neutron drip and neutron stars, Pulsars.

(25 % Weightage)

Unit-3

The Birth of Cosmic Ray: Stellar evolution, the *pp* chain, Solar neutrinos, Supernova explosions, Supernova neutrinos, Supernova remnants, Acceleration of cosmic rays: Stochastic acceleration of charged particles, Fermi mechanism, acceleration with energy loss, energy spectra, Interstellar matter and magnetic field, Diffuse galactic gamma rays, Comsic rays in atomsphere, Cosmic rays underground

(25 % Weightage)

Unit-4

Ultra High Energy Cosmic Ray (UHECR) : Cosmic microwave background, UHECR interactions on the microwave background, Propagation of UHE protons and nuclei, Possible astrophysical sources of UHECR, GZK cutoff, current status of the field, High energy neutrino and gamma-ray astronomy (review), Grapes Experiment (otty)

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Basic equations of stellar structure
5-8	Stellar observational data and HR diagrams
9-12	Nucleosynthesis in star
13-16	Stellar models and experimental confirmatio
17-20	Stellar evolution
21-24	Degeneracy pressure of a Fermi gas, Supernova, Structure of white dwarfs, Chandrasekhar mass limit
25-28	Neutron drip and neutron star
28-32	Birth of Cosmic Ray: Stellar evolution, the pp chain
32-36	Acceleration of cosmic rays: Stochastic acceleration of charged particles, Fermi mechanism
36-40	Acceleration with energy loss, energy spectra
41-44	Ultra High Energy Cosmic Ray: UHECR interactions on the microwave background, Propagation of UHE protons and nuclei

45-48	Possible astrophysical sources of UHECR, GZK cutoff
49-52	Current status of the field
53-56	High energy neutrino
57-60	gamma-ray astronomy and Grapes Experiment (otty)

Essential Readings:

1. Astrophysics for Physicists, Arnab Rai Choudhuri, Cambridge University Press.
2. High Energy Cosmic Rays , Todorstanev, Springer
3. Cosmic Rays and Particle Physics, By Thomas K. Gaisser, Cambridge University Press.
4. Dina Prialnik: An Introduction to the Theory of Stellar Structure and Evolution, Latest Edition, Cambridge University Press

Additional/Advance/Further Readings:

1. High Energy Radiation from Black Holes: Gamma Rays, Cosmic Rays, and Neutrinos, By Charles D. Dermer, Charles Dermer, GovindMenon, Princeton University Press.
2. Ultra-high Energy Particle Astrophysics, By Shigeru Yoshida, Nova Science Publishers, Inc. New York.
3. Malcolm Longair, High Energy Astrophysics, vols 1-2, Latest Edition, Cambridge University Press.
4. B.W. Carroll & DA Ostlie, An Introduction to Modern Astrophysics, Latest Edition, Addison-Wesley

Course Title: Nuclear Reactor Physics

Course Code	PHY91DE21404	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
1 **Methods of Content Interaction**	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are to

1. acquaint the students with the different types of nuclear reactors
2. introduce a theory of neutron interactions with matter.
3. acquaint the students with the theory of nuclear fuels
4. acquaint the students with radiation shielding
5. orient the student with reactor licensing, safety and environment

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. describe the nuclear energy and neutron sources.
2. describe the different types of nuclear reactors.
3. explain the different forms of nculear fuels.
4. demonstrate a working knowledge of radiation shielding.

Course Contents:

Unit-1

Types of Nuclear Reactors: Introduction:- Types of Nuclear Energy, Neutron Classification and Neutron Sources, Interactions of Neutrons with Matter. Definition of Neutron Flux and Fluence, Neutron Cross Section, Reactor Flux Spectrum, Types of Reactors:- Simple Reactor Design and Operation, Generation-I, 11, III, IV Reactors, Boiling Water Reactor (BWR), Pressurized Water Reactor (PWR), CANDU Reactor, RMBK Reactor, Fast Breeder Test Reactor, Fusion Reactor, Reactor Core Materials:- Structural/Fuel Cladding Materials, Moderators and Reflectors Control Materials, Coolants, Shielding Materials, Reactor start Up and Shutdown Principles, Nuclear Reactors in India,

(25 % Weightage)

Unit-2

Nuclear Fuels: Introduction to Uranium, Plutonium and Thorium Fuels:- Crystal Structure and Physical Properties, Extraction, Alloying, Fabrication and Radiation effects, Ceramic Fuels:- Ceramic Uranium Fuels, Uranium Dioxide (Urania), Uranium Carbide, Uranium Nitride, Plutonium-Bearing Ceramic Fuels, Thorium-Bearing Ceramic Fuels

(25 % Weightage)

Unit-3

Neutrino Diffusion and Moderation : Neutron Flux, Fick's Law, Equation of Continuity, Diffusion Equation.

Neutron-Nuclear Reactions: Neutron-Induced Nuclear Fission, Stable Nuclides, Binding Energy, Threshold External Energy for Fission, Neutron-Induced Fission, Neutron Fission Cross Sections, Products of the Fission Reaction, Energy Release,

(25 % Weightage)

Unit-4

Radiation shielding : Gamma-Ray Shielding, Infinite Planar and Disc Sources, Line Source, Internal Sources, Multilayered Shields, NuclearReactorShielding, Removal Cross-Sections, Reactor Shield Design: Removal-Attenuation Calculatons, Removal-Diffusion Method, Exact Methods, Coolant Activation, Ducts in Shields.

Reactor Licensing, Safety and environment: Governmental Authority and Responsibility, Reactor Licensing, Principles of Nuclear Power Plant Safety, Dispersion of Effluents from Nuclear Facilities, Radiation Doses from Nuclear Plants, Reactor Siting, Reactor Accidents, Accident Risk Analysis, Environmental Radiation Doses.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Introduction:- Types of Nuclear Energy, Neutron Classification and Neutron Sources.
5-8	Interactions of Neutrons with Matter. Definition of Neutron Flux and Fluence, Neutron Cross Section, Reactor Flux Spectrum
9-12	Types of Reactors
13-16	Reactor Core Materials:- Structural/Fuel Cladding Materials, Moderators and Reflectors Control Mat erials, Coolants
17-20	Reactor start Up and Shutdown Principle, Nuclear Reactors in India
21-24	Introduction to Uranium, Plutonium and Thorium Fuels Shielding Materials
25-28	Crystal Structure and Physical Properties, Extraction, Alloying, Fabrication and Radiation effect
28-32	Ceramic Fuels:- Ceramic Uranium Fuels, Uranium Dioxide (Urania), Uranium Carbide, Uranium Nitride
32-36	Plutonium-Bearing Ceramic Fuels, Thorium-Bearing Ceramic Fuels
36-40	Neutrino Diffusion and Moderation : Neutron Flux, Fick's Law, Equation of Continuity, Diffusion Equation Binding Energy

41-44	Neutron-Nuclear Reactions: Neutron-Induced Nuclear Fission, Stable Nuclides, Binding Energy
45-48	Neutron-Induced Fission, Neutron Fission Cross Sections, Products of the Fission Reaction, Energy Release
49-52	Radiation shielding
53-56	Reactor Shield Design
57-60	Reactor Licensing, Safety and environment

Essential Readings:

1. An Introduction to Nuclear Materials - Fundamentals and Applications, K. Linga Murty and Jndraj it Charit (Wiley-VCH Verlag, Gennany).
2. John.R Lamarsh, Introduction to Nuclear Reactor Theory, Third Edition, Prentice Hall Upper Saddle River, New Jersey.
3. Paul .F. Zweifel, Reactor Physics, McGraw Hill Book Company (1973) India.
4. Richard Stepheson, Introduction to nuclear Engineering, McGraw Hill Book Company (1974) New York.
5. Suresh Gard, Feroz Ahmed and L. S Kothari, Physics of Nuclear Reactors, Tata McGraw Hill Pub. Co. Ltd, London.
6. Samuel Glasstone and Edmund , Nuclear reactor theory

Additional/Advance/Further Readings:

1. A K Suri (BARC, Mumbai) Material development for India's nuclear power programme Sadhana, Vol. 38, Part5, October 2013, pp. 859-895.
2. C V Sundaram and S L Mannan, (IGCAR Kalpakkam) Nuclear Fuels and development of nuclear fuel elements, Sadhana Vol.l4, Part I,June 1989, pp 21-57.

Course Title: Experimental Techniques in Nuclear and Particle

Course Code	PHY91DE21504	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The objective of this course is to gain the basic knowledge of modern experimental techniques in nuclear and particle physics. The course covers interaction of radiation with matter and summarizes different type of detectors such as gaseous, liquid, solid state, and scintillation detectors. In addition, this course introduces several signal processing techniques based on nuclear instruments.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. describe the basic interaction of charged and neutral particle with matter.
2. describe the basic concepts of gaseous detectors and its operation.
3. describe the working of solid state detectors and its operation.
4. explain the mechanisms of the scintillation process.
5. understand how to obtain the data from different type of detectors.

Course Contents:

Unit-1

Interaction of Radiation with Matter: Inverse Square Law, Cross Section, Mean Free Path, Radiation Length, Conservation Laws; Types of Particle Interactions : Elastic Scattering, Inelastic Scattering, Annihilation, Bremsstrahlung, Cherenkov Radiation; Interaction of Photons with Matter: Photo electric Effect, Compton Scattering, Thompson Scattering, Rayleigh Scattering, Pair Production, Measuring Attenuation Coefficient, Mixtures and Compounds, Stacked Materials; Interaction of Heavy Charged Particles with Matter: Bragg Curve, Energy Straggling, Range Straggling, Range of α-Particles, Range of Protons, Interaction of Electrons with Matter Interaction of Electrons with Matter: Ionization, Moeller Scattering, Bhabha Scattering, Electron-Positron Annihilation, Bremsstrahlung, Cherenkov Radiation; Interaction of Neutral Particles with Matter: Elastic Scattering, Inelastic Scattering, Transmutation, Radiative Capture, Spallation.

(25 % Weightage)

Unit-2

Gas Filled Ionization Detectors : Production of Electron-Ion Pairs , Diffusion and Drift of Charges in Gases, Regions of Operation of Gas Filled Detectors, Features governing behaviour of Gas Ionization Detectors - Ionization Chambers - Proportional Counters - Geiger Muller Counters, Sources of Error in Gaseous Detectors, Detector Efficiency.
Liquid Filled Detectors : Properties of Liquids, Liquid Ionization Chamber, Liquid Proportional Counters, Commonly Used Liquid Detection Media, Sources of Error in Liquid Filled Ionizing Detectors, Cherenkov Detectors, Bubble Chamber, Liquid Scintillator Detectors.

(25 % Weightage)

Unit-3

Solid State Detectors : Semiconductor Detectors Structure of Semiconductors, Charge Carriers Distribution, Intrinsic, Compensated, and Extrinsic Semiconductors, Doping, Mechanism and Statistics of Electron-Hole Pair Production, Charge Conductivity, Materials Suitable for Radiation Detection, pn-Junction, Modes of Operation of a pn-Diode, Specific Semiconductor Detectors, Radiation Damage in Semiconductors, Diamond Detectors, Thermoluminescent Detectors.
Scintillation Detectors: Scintillation Mechanism and Scintillator Properties, Organic Scintillators, Inorganic Scintillators Transfer of Scintillation Photons, Photodetectors, PhotodiodeDetectors, Avalanche Photodiode Detectors (APD)

(25 % Weightage)

Unit-4

Signal Processing: Preamplification, Signal Transport, Pulse Shaping, Filtering, Amplification, Discrimination, Analog to Digital Conversion, A/D-Conversion Related Parameters, A/D Conversion Methods, Digital Signal Processing, Electronics Noise.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Interaction of Radiation with Matter and Types of Particle Interactions
5-8	Interaction of Photons with Matter and Interaction of Photons with Matter
9-12	Interaction of Heavy Charged Particles with Matter and Interaction of Electrons with Matter
13-16	Interaction of NeutralParticles with Matter
17-20	Gas Filled Ionization Detectors
21-24	Regions of Operation of Gas Filled Detectors
25-28	Liquid Filled Detectors
28-32	Liquid Filled Ionizing Detectors, Cherenkov Detectors, Bubble Chamber, Liquid Scintillator Detectors
32-36	Semiconductor Detectors: Structure of Semiconductors, Charge Carriers Distribution, Intrinsic, Compensated, and Extrinsic Semiconductors, Doping, Mechanism and Statistics of Electron-Hole Pair Production,
36-40	Charge Conductivity, Materials Suitable for Radiation Detection, pn-Junction, Modes of Operation of a pn-Diode, Specific Semiconductor Detectors, Radiation Damage in Semiconductors
41-44	Diamond Detectors, Thermoluminescent Detectors.

45-48	Scintillation Detectors, Photodetectors, PhotodiodeDetectors, Avalanche Photodiode Detectors
49-52	Preamplification, Signal Transport, Pulse Shaping, Filtering, Amplification, Discrimination
53-56	Analog to Digital Conversion, A/D-Conversion Related Parameter
57-60	A/D Conversion Methods, Digital Signal Processing, Electronics Noise

Essential Readings:

1. Physics and Engineering of Radiation Detection by Syed Naeem Ahmed, Academic Press, Elsevier, 2007.
2. Radiation detection and measurement by Glenn F. Knoll (Wiley), 2010.
3. Techniques in Nuclear and particle Experiments by W.R. Leo (Springer), 1994.

Additional/Advance/Further Readings:

1. Introduction to Experimental Particle Physics by Richard Fernow (Cambridge University Press), 2001.
2. Detectors for particle radiation by Konrad Kleinknecht (Cambridge University Press), 1999.

Course Title: Advance Particle Physics

Course Code	PHY92DC21104	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	IV	Contact Hours	60 (L) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are

1. To deepen understanding of Symmetries and Quarks
2. To learn how to apply group theory in particle physics
3. To prepare students for research work in nuclear and particle physics.
4. To overview basic relativistic quantum mechanics and quantum electrodynamics for particle physics.
5. To prepare students for courses in quantum field theory and gauge theory.
6. To acquaint the students about Feynman rules for quantum electrodynamics
7. To acquaint the students with scattering amplitudes and decay width calculations
8. To orient the student with quantum Chromodynamics.

Course Learning Outcomes:

Upon completion of this course, the student should:

1. able to undertstand symmetries and groups.
2. be familiar with quantum electrodynamics
3. understand the rules for scattering amplitudes.
4. understand the concepts of parton model and Bjorken scaling
5. understand the basic concepts of quantum chromodynamics.
6. able to read, understand and explain scholarly journal articles in nuclear and particle physics

Course Contents:

Unit-1

Symmetries and Quarks : Symmetries in Physics, Symmetries and Groups (Brief Introduction), Group SU(2), Combining Representations, Finite Symmetry Groups: P and C, SU(2) of Isospin, Isospin for Antiparticles, Group SU(3), Example of an SU(3) Group: Isospin and Strangeness, Quark-Antiquark States : Mesons, Three-Quark States: Baryons, Magnetic Moments, Heavy Quarks: Charm and Beyond, Hadron Masses, Color Factors. (25 % Weightage)

Unit-2

Quantum Electrodynamics (QED) : Nonrelativistic Quantum Mechanics, Lorentz Covariance and Four-Vector Notation, The Klein-Gordon Equation, The Feynman-Stiickelberg Interpretation, Nonrelativistic Perturbation Theory, Rules for Scattering Amplitudes, Feynman-Stiickelberg Approach, Electron (Spinless) in an Electromagnetic Field , Electron-Muon Scattering (Spinless), The Cross Section in Terms of the Invariant Amplitude, The Decay Rate Electron-Electron Scattering (Spinless), Electron-Positron Scattering: An Application of Crossing, Invariant Variables, The Origin of the Propagator.

(25 % Weightage)

Unit-3

Electrodynamics of Spin-half Particles: An Electron Interacting with an Electromagnetic Field, Mo11er Scattering, Electron-Muon Scattering (spin), Trace Theorems and Properties of γ-Matrices, Helicity Conservation at High Energies, Photons Polarization Vectors, Electron Propagator, Photon Propagator, Massive Vector Particles, Real and Virtual Photons, Compton Scattering, Pair Annihilation, Feynman Rules for QED,

(25 % Weightage)

Unit-4

Electrodynamics of Quarks and Hadrons: Electron-Quark Interactions, Hadron Production in e^+e^- Scattering, Elastic Electron-Proton Scattering, Inelastic Electron-Proton Scattering, The Parton Model and Bjorken Scaling, Quark Distribution Functions. Feynman Rules for Chromodynamics, The Quark-Quark Interaction, Pair Annihilation in QCD, Asymptotic Freedom. g-2 anomaly.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Symmetries in Physics, Symmetries and Groups
5-8	Group SU(2), Combining Representations, Finite Symmetry Groups: P and C, SU(2) of Isospin, Isospin for Antiparticles
9-12	Group SU(3), Example of an SU(3) Group: Isospin and Strangeness, Quark-Antiquark States : Mesons, Three-Quark States: Baryons, Magnetic Moments
13-16	Heavy Quarks: Charm and Beyond, Hadron Masses, Color Factors.
17-20	Nonrelativistic Quantum Mechanics, Lorentz Covariance and Four-Vector Notation, The Klein-Gordon Equation, The Feynman-Stiickelberg Interpretation

21-24	Nonrelativistic Perturbation Theory, Rules for Scattering Amplitudes, Feynman-Stiickelberg Approach, Electron (Spinless) in an Electromagnetic Field , Electron-Muon Scattering (Spinless), The Cross Section in Terms of the Invariant
25-28	Electron-Muon Scattering (Spinless), The Cross Section in Terms of the Invariant Amplitude, The Decay Rate Electron-Electron Scattering (Spinless)
28-32	Electron-Positron Scattering: An Application of Crossing, Invariant Variables, The Origin of the Propagator
32-36	Electrodynamics of Spin-half Particles: An Electron Interacting with an Electromagnetic Field, Mo11er Scattering, Electron-Muon Scattering (spin)
36-40	Trace Theorems and Properties of γ-Matrices, Helicity Conservation at High Energies
41-44	Photons Polarization Vectors, Electron Propagator, Photon Propagator, Massive Vector Particles, Real and Virtual Photons
45-48	Electrodynamics of Quarks and Hadrons: Electron-Quark Interactions, Hadron Production in e^+e^- Scattering, Compton Scattering, Pair Annihilation,
49-52	Feynman Rules for QED, Elastic Electron-Proton Scattering
53-56	Inelastic Electron-Proton Scattering, The Parton Model and Bjorken Scaling, Quark Distribution Functions
57-60	Feynman Rules for Chromodynamics, The Quark-Quark Interaction , Pair Annihilation in QCD, Asymptotic Freedom, g-2 anomaly

Essential Readings:

1. Introduction to Elementary Particles by D. Griffiths (2nd Ed., Wiley-VCH, 2008).
2. Quarks and Leptons, by F. Halzen and A.D. Martin (Wiley 1984).
3. Particle Physics, by B.R. Martin and G. Shaw (Wiley 2008).
4. Particle and Astroparticle Physics, by Utpal Sarkar, Taylor & Francis Group, LLC

Additional/Advance/Further Readings:

1. Elementary Particles and the Laws of Physics by R. P. Feynman and S. Weinberg (Cambridge University Press, 1999)
2. Introduction to Elementary Particle Physics by A. Bettini (Cambridge University Press, 2008)
3. Elementary Particle Physics by S. Gasiorowicz (John Wiley, 1966)

Course Title: Nuclear and Particle Physics Lab. – II

Course Code	PHY92DC21204	**Credits**	4
L+T+P	0+0+4	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	120(P) Hours

Course Type	Discipline Based Core
Nature of the Course	Practical
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Mainly Practical sessions in laboratory
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (15 % Record + 15% Sessional Performance) 2. 70% - End Term External Examination (50% End term Practical Exam + 20% comprehensive Viva)

Course Objectives:

The objectives of laboratory courses are coherent with the objectives of theory courses. It is considered that laboratory also helps making sense of particular subject. The main objectives of this course are to enable students to:

1. enhance the understanding of the students of procedural knowledge of nuclear physics.
2. enhance the ability of the students to explain the processes and applications related to nuclear and particle physics.
3. develop an ability of the students to handle the sophisticated apparatus carefully, and use the resources wisely.
4. develop interest and motivate the master students towards experiment reserach.
5. enhance the scientific understanding of radiation safety.
6. develop ability to work together.
7. develop an ability to express themselves coherently and logically.
8. develop mental and motor abilities.

Course Learning Outcomes:

After completion of the course the learners will be able to:

1. handle the sophisticated detectors.
2. express the basic concepts of nuclear physics in more general language.
3. express the radioactive decays.

4. express the types of gamma decay.
5. list the types of beta decays and can express reaction equations and related Q values and enegy of beta particles.
6. demonstrate knowledge of personal radiation safety
7. Demonstrate appropriate data analysis skills.

Course Contents:

1. Geiger Counter Experiment: Capturing and Dectecting Radon in the Environment
2. Backscattering of Beta particles
3. Measurement of short half-life
4. Linear Absorption Coefficient
5. Energy calibration of Gamma Ray Spectrometer (Study of linearity)
6. Energy Analysis of an Unknown Gamma Source
7. Study the activity of a given Gamma Source using relative method and absolute Method.
8. Study the mass absorption coefficient for 662 keV gamma rays in lead
9. To study the absorption of gamma-radiation by different media like Lead, Aluminium, and Plastic.
10. Stuy the photoelectric absorption of photons and verify the strong dependence of this process on the atomic number of the absorbing material.
11. LabView: reading and writing to text files.
12. LabView: Design a coincidence trigger using FPGA.
13. Comapre the energy resoltion of NaI and HPGe Detectors.

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Particle Accelerator Physics

Course Code	PHY92DE21304	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce the students to the physics and technology of charged particle accelerators. The objectives of this course are :

1. To give an insight about several types of accelerators and the principles of the particle transport.
2. To provide students with an understanding of the nature of fundamentals of accelerators and the required components and structures.
3. To allow the students to become familiar with technological components of the accelerators and beam instrumentation.
4. To introduce a theory of synchrotron radiation.
5. To acquaint the students with Linear Beam optics.
6. To acquaint the students with Injection and Extraction.
7. To orient the student beam monitors by using the key parameters

he students are expected . Furthermore, they will and will be able to analyze experimental observations in terms of fundamental beam dynamics.

Course Learning Outcomes:

After completion of the course the learners will be able :

1. to understand the basic workings of accelerators and their components.
2. to describe the Linear accelerator, Cyclotron, Microton, Betatron, Synchrotron.
3. comprehend basic principles and definitions of beam dynamics
4. understand the basic aspects of linear Beam optics

5. describe the basic components storage rings.
6. understand the basic concepts of Injection and Extraction.
7. comprehend the methodology of diagnostics of beam.
8. to describe the RF systems for particle accerleration.
9. to describe the damping of synchrotron oscillations.

Course Contents:

Unit-1

Introduction to accelerators : Direct-voltage accelerator, Cockroft-Walton Cascade generator, Marx generator, Van de Graaff accelerator, Linear accelerator, Cyclotron, Microton, Betatron, Synchrotron. Particle Production by colliding Beams.

(25 % Weightage)

Unit-2

Synchrotron Radiation: Radiation from relativistics particles, Angular distribution of synchrotron radiation, Time dependence and frequency spectrum of the radiation Storage rings for synchrotron radiation.

Linear Beam optics: Charged particle motion in a magnetic field, Equation of motion in a co-moving coordinate system, Beam streeing magnets, Particle trajectories and transfer matrices, Beta function and betatron oscillation, Phase space ellipse and Liouville's Theorem. (25 % Weightage)

Unit-3

Injection and Extraction: The process of inhection and extraction, Partilce Sourcces, Injection of high proton beams, Injection into an electron storge ring, Kicker and septum magnets.

RF systems for particle accerleration: Waveguide and their properties, Resonant cavites, Accelerating structures for linacs, Klystrons as power generators for accelerators, Phase focusinhg and synchrotron frequency, Region of phase stability. (25 % Weightage)

Unit-4

Radiative effects: Damping of Synchrotron oscillations, Damping of betatron oscillations, Robinson theorem, beam emittance, Luminosity: Beam current restriction due to the space charge effect, Min-Beta principle,

Diagnostics : Fluorescent screen, Faraday Cup, Wall current monitor, current transformer, Dertermination of the beam lifetime in a storage ring, Measurement of the momentum and energy of a particle beam, Measurement of the optical parameter of the beam.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Introduction to accelerators: Direct-voltage accelerator, Cockroft-Walton Cascade generator, Marx generator,
5-8	Van de Graaff accelerator, Linear accelerator, Cyclotron
9-12	Microton, Betatron, Synchrotron. Particle Production by colliding Beams

13-16	Synchrotron Radiation: Radiation from relativistics particles, Angular distribution of synchrotron radiation
17-20	Time dependence and frequency spectrum of the radiation Storage rings for synchrotron radiation.
21-24	Linear Beam optics: Charged particle motion in a magnetic field, Equation of motion in a co-moving
25-28	coordinate system, Beam streeing magnets, Particle trajectories and transfer matrices,
28-32	Beta function and betatron oscillation, Phase space ellipse and Liouville's Theorem
32-36	Injection and Extraction: The process of inhection and extraction, Partilce Sourcces, Injection of high proton beams
36-40	Injection into an electron storge ring, Kicker and septum magnets
41-44	RF systems for particle accerleration: Waveguide and their properties, Resonant cavites, Accelerating structures for linacs
45-48	Klystrons as power generators for accelerators, Phase focusinhg and synchrotron frequency, Region of phase stability
49-52	Radiative effects: Damping of Synchrotron oscillations, Damping of betatron oscillations, Robinson theorem, beam emittance
53-56	Luminosity: Beam current restriction due to the space charge effect, Min-Beta principle
57-60	Diagnostics

Essential Readings:

1. The Physics of Particle Accelerators by Klaus Wille, European Scientfic Institute.
2. Particle Accelerator Physics, Vol I and II, H. Wiedmann, (Springer Verlag), 1998.
3. Particle Accelerators, M.S. Livingston and J.P. Blewel, (McGraw-Hill Book Press), 1962.
4. An Introduction to the Physics of High Energy Accelerators by D. A. EDWARDS M.J. SYPHERS, WILEY-VCH Verlag GmbH & Co. KGaA

Additional/Advance/Further Readings:

1. Nuclear Spectroscopy and Reactions Part-A, Ed. J. Cerny, (Academic Press), 1974.
2. Theory of Resonance Linear Accelerators by I.M. Kapchenkey, (Harwood Academic Publishers).
3. A Brief History and Review of Accelerators by P.J. Bryant CERN, Geneva, Switzerland

Course Title: Biography of Indian Scientists

Course Code	PHY81OE22104	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	I	Contact Hours	60(L) Hours

Course Type	Open Elective (Interdisciplinary) Course
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Value Addition, Indian Knowledge Systems
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term Examination

Course Objectives:

The main objective of this course is to introduce the students with the indian contribution to the world in the field of science and encourage them to get inspiration from the life of different indian scientists.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. develop a global understanding of science in general.
2. keep himself/herself motivated for whole life.
3. develop an idea of societal upliftment through science.

Course Contents:

Unit-1

Historical Accounts of Ancient Indian Scientists: Baudhaayana, Aaryabhata, Brahmagupta, Bhaaskaraachaarya, Mahaaviiraachaarya, Kanaad, Varaahamihira, Naagaarjuna, Sushruta, Charak, Vaagbhatta, Patanjali, PaNini, Chaanakya; Pingala, Lagaadha, Bharata Muni, Maadhava, Dhanvantari, Kapila Muni, Bhaaradwaj Muni.

(50 % Weightage)

Unit-2

Biographical Sketch of Modern Indian Scientists: Sir J C Bose, Prafulla Chandra Roy, Srinivas Ramanujan, Sir C Venkata Raman, Meghnad Saha, S N Bose, Shanti Swarup Bhatnagar, Homi Jehangir Bhabha, S Chandrashekhar, Vikram Sarabhai, C R Rao, K V Chandrashekhar, Har Govind Khurana, G N Ramachandran, Harish Chandra, M K Vainu Bappu, M Visvesvaraya, Subhash Mukhopadhyay, Raja Ramanna, A P J Abdul Kalam, Vashishtha Narayan Singh

(50 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-10	Baudhaayana, Aaryabhata, Brahmagupta, Bhaaskaraachaarya, Mahaaviiraachaarya, Kanaad, Varaahamihira
11-20	Naagaarjuna, Sushruta, Charak, Vaagbhatta, Patanjali, PaNini, Chaanakya
21-30	Pingala, Lagaadha, Bharata Muni, Maadhava, Dhanvantari, Kapila Muni, Bhaaradwaj Muni
31-40	Sir J C Bose, Prafulla Chandra Roy, Srinivas Ramanujan, Sir C Venkata Raman, Meghnad Saha, S N Bose, Shanti Swarup Bhatnagar
41-50	Homi Jehangir Bhabha, S Chandrashekhar, Vikram Sarabhai, C R Rao, K V Chandrashekhar, Har Govind Khurana, G N Ramachandran
51-60	Harish Chandra, M K Vainu Bappu, M Visvesvaraya, Subhash Mukhopadhyay, Raja Ramanna, A P J Abdul Kalam, Vashishtha Narayan Singh

Essential Readings:

1. Biography of Indian Scientist - A Chattopadhyay
2. Bharat Ke Mahan Vaigyanik Famous Indian Scientists And Their Biographies - Arvind Gupta

Additional/Advance/Further Readings:

1. The golden age of Indian mathematics - S Parameswaran; Swadeshi Science Movement Kerala
2. The history of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited

Course Title: Statistical Mechanics

Course Code	PHY82DE22202	Credits	2
L+T+P	2+0+0	Course Duration	One Semester
Semester	II	Contact Hours	30(L) Hours

Course Type	Open Elective (Interdisciplinary) Course
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Enhancement
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal 2. Assessment 70% - End Term Examination

Course Objectives:

The main objective of this course is to introduce the basic concepts of statistical mechanics to the students.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. differentiate classical and quantum statistics.
2. derive thermodynamics of simple systems using statistical tools.
3. grasp the concept of fluctuations and its relation to dissipation.

Course Contents:

Unit-1

Classical statistical mechanics: Basic postulates of statistical mechanics, Macro-and micro states – Statistical equilibrium– Phase space, Density function -– Liouville's theorem, Ensemble: micro-canonical, canonical, grand canonical; Partition function–connection with thermodynamics; Statistical definition of entropy—Boltzmann equation and its significance; Ideal monoatomic gas, Gibbs' paradox, Equipartition theorem, specific heat of solids.

(10 Lectures)

Unit-2

Quantum statistical mechanics: Basic concepts – Quantum ideal gas, Identical particles and symmetry requirements, Bose-Einstein statistics, black body radiation, Bose- Einstein condensation, Fermi-Dirac statistics, Ideal Fermi gas, properties of simple metals, Quantum statistics in the classical limit.

(10 Lectures)

Unit-3

Irreversible processes and fluctuations: Random walk in one dimension, Brownian motion, Langevin equation, Fluctuation dissipation theorem, Einstein relation, Fourier analysis of random functions, Wiener-Khintchine relations Nyquist's theorem, Fluctuations and Onsager relations.

(10 Lectures)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Basic postulates of statistical mechanics, Macro-and micro states – Statistical equilibrium– Phase space, Density function -– Liouville's theorem, Ensemble: micro-canonical, canonical, grand canonical
6-10	Partition function–connection with thermodynamics; Statistical definition of entropy—Boltzmann equation and its significance; Ideal monoatomic gas, Gibbs' paradox, Equipartition theorem, specific heat of solids.
11-15	Basic concepts of quantum statistics – Quantum ideal gas, Identical particles and symmetry requirements, Bose-Einstein statistics, black body radiation, Bose- Einstein condensation
16-20	Fermi-Dirac statistics, Ideal Fermi gas, properties of simple metals, Quantum statistics in the classical limit.
21-25	Random walk in one dimension, Brownian motion, Langevin equation, Fluctuation dissipation theorem, Einstein relation
26-30	Fourier analysis of random functions, Wiener-Khintchine relations Nyquist's theorem, Fluctuations and Onsager relations.

Essential Readings:

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
2. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
3. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill.
4. Statistical Mechanics, K. Huang.
5. B. B. Laud, Fundamentals of Statistical Mechanics, New Age International Publication (2003).

Additional/Advance/Further Readings:

1. Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall.
2. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
3. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
4. An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press.

Course Title: Elements of Ancient Indian Sciences

Course Code	PHY91OE22304	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	60(L) Hours

Course Type	Open Elective (Interdisciplinary) Course
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Enhancement, Value Addition, Indian Knowledge Systems
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term Examination

Course Objectives:

The main objective of this course is to acquaint students with different elements of scientific tradition in ancient India.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. understand the basic concepts behind the terminologies used in ancient texts.
2. explain the meaning of different ideas of ancient India in proper contexts.

Course Contents:

Unit-1

Basic Concepts: Some essential definitions and fundamentals of indian knowledge systems

(10 Lectures)

Unit-2

Elements of different Sciences: Ancient Indian Mathematics and its similarities and contrast from modern mathematics; Vedantic understanding of the number system and its implications in modern physics; Ancient Indian Astronomy; Elements of modern physics in ancient indian sciences; The science of language; Sanskrit as world's most mathematical human language; Ayurveda - The science of well-being; Social and economic sciences; Science of preservation of knowledge (Indian Education System); Agricultural Sciences; Metallurgical Sciences; Computer Science; Civil Engineering; Architecture; Chemistry; Mechanical Engineering

(40 Lectures)

Unit-3

Other topics: Ancient indian sciences in modern context; Different endeavours of modern day contextualisation of ancient indian sciences

(10 Lectures)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-10	Some essential definitions and fundamentals of indian knowledge systems
11-20	Ancient Indian Mathematics and its similarities and contrast from modern mathematics; Vedantic understanding of the number system and its implications in modern physics
21-23	Ancient Indian Astronomy
24-27	Elements of modern physics in ancient indian sciences
28-32	The science of language; Sanskrit as world's most mathematical human language
21-24	General Theory of Deformed Nuclei, Giant Resonances, Nilsson Model
25-28	Types of Reactions, Energy and Mass Balance, Conservation Laws for Nuclear Reactions
28-32	Cross-Sections, Exoergic and Endoergic Reactions, Behaviour of Cross-Sections near Threshold, Inverse Reaction, Qualitative Features of Nuclear Reactions
33-37	Ayurveda
38-40	Social and economic sciences
41-42	Science of preservation of knowledge (Indian Education System)
43-44	Agricultural Sciences
45-50	Metallurgical Sciences; Computer Science; Civil Engineering; Architecture; Chemistry; Mechanical Engineering
51-53	Ancient indian sciences in modern context
54-60	Different endeavours of modern day contextualisation of ancient indian sciences

Essential Readings:

1. Indian Science and Technology in the Eighteenth Century: Some Contemporary European Accounts - Dharampal; Other India Press
2. The History of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited
3. The golden age of Indian mathematics - S Parameswaran; Swadeshi Science Movement Kerala
4. Science in Samskrita; Samskrita Bharati
5. Pride of India: A glimpse into India's scientific heritage; Samskrita Bharati

Additional/Advance/Further Readings:

1. The Wonder that is Sanskrit - Sampad & Vijay; Auro Publications

Course Title: Crystallography, Imperfections in Crystals and Diffraction Techniques

Course Code	PHY91DE22403	Credits	3
L+T+P	3+0+0	Course Duration	One Semester
Semester	III	Contact Hours	45(L) Hours

Course Type	Discipline Based Core Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are

1. To provide broad knowledge of the Crystallography.
2. To acquaint students about the important Crystal Structures
3. To facilitate the understanding of Phase identification by indexing
4. Generate understanding about the concept of Zone Axis
5. Analyze the environmental aspects of renewable energy resources.

Course Learning Outcomes:

After completion of this course, the student should able to :

1. Describe different materials at the structural level.
2. Explain Structure of common metals, alloys, ionic, covalent and molecular crystals.
3. Understand basic structure.
4. Understanding about Powder diffraction, Space group symmetries.
5. Understanding of different Diffraction techniques and determination of structure by using these techniques.
6. Determination of Phase by diffraction anaylsis.

Course Contents:

Unit-1

Close packing of spheres. Structure of common metals, alloys, ionic, covalent and molecular crystals, concepts of space group, symmetries, and its relevance to crystal structure. General procedure for working out the details of space groups with illustrations from triclinic, monoclinic and orthorhombic systems. Wyckoff positions. Principles of crystal structure analysis. Structure factor calculations, Space group extinctions. Electron density functions. Phase problem. Patterson functions.

(30 % Weightage)

Unit-2

Production and properties of x-rays: Continuous and characteristic spectrum. Principle of Powder diffractometer, Interaction of x-rays with matter.Laue equations.Bragg's law. Reciprocal lattice concept and its applications to rotation, Powder diffractometry. Application of powder method, Determination of relative structure amplitudes from measured intensity (Lorentz and Polarization factors), Direct methods in crystallography. Debye Scherrer, Guinier and Bragg-Brentano geometries for powder diffractometers. General intensity expression for powder diffraction. Rietveld refinement technique. Quantitative phase analysis and microstructure determination. Limitations of powder method. Single crystal diffractometers. Indexing of electron diffraction patterns

(40 % Weightage)

Unit-3

Mechanism of plastic deformation in solids, Stress and strain fields of screw and edge dislocations, Elastic energy of dislocations, Forces between dislocations, Stress needed to operate Frank-Read source, Dislocations in fcc, hcp and bcc lattices, Partial dislocations and stacking faults in close-packed structures. Experimental method of detecting dislocations and stacking faults, Electron Microscopy: Kinematical theory of diffraction contrast and lattice imaging.

(30 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Close packing of spheres. Structure of common metals, alloys, ionic, covalent and molecular crystals
6-10	concepts of space group, symmetries, and its relevance to crystal structure. General procedure for working out the details of space groups with illustrations from triclinic, monoclinic and orthorhombic systems.
11-15	Wyckoff positions. Principles of crystal structure analysis. Structure factor calculations, Space group extinctions. Electron density functions. Phase problem. Patterson functions
16-20	Production and properties of x-rays: Continuous and characteristic spectrum,Principle of Powder diffractometer.
20-22	Interaction of x-rays with matter.Laue equations.Bragg's law. Reciprocal lattice concept and its applications to rotation, Powder diffractometry.
23-26	Application of powder method, Determination of relative structure amplitudes from measured intensity (Lorentz and Polarization factors), Direct methods in crystallography.
27-30	Debye Scherrer, Guinier and Bragg-Brentano geometries for powder diffractometers, General intensity expression for powder diffraction.

31-35	Rietveld refinement technique. Quantitative phase analysis and microstructure determination. Limitations of powder method.
36-40	Single crystal diffractometers. Indexing of electron diffraction patterns
41-45	Mechanism of plastic deformation in solids, Stress and strain fields of screw and edge dislocations
46-50	Elastic energy of dislocations, Forces between dislocations, Stress needed to operate Frank-Read source,
50-55	Dislocations in fcc, hcp and bcc lattices, Partial dislocations and stacking faults in close-packed structures.
56-60	Experimental method of detecting dislocations and stacking faults, Electron Microscopy: Kinematical theory of diffraction contrast and lattice imaging.

Essential Readings:

1. Crystallography for Solid State Physics: Verma and Srivastava.
2. X-ray Crystallography: Azarof.
3. Elementary Dislocation Theory: Weertman and Weertman.
4. Crystal Structure Analysis: Buerge.
5. Electron Microscopy of Thin Crystals: Hirsh.

Additional/Advance/Further Readings:

1. X-ray Diffraction B.D. Culty
2. X-ray Diffraction B E.Warren.
3. Introduction of Solid State Theory O. Madelung
4. Principles of the theory of solids J.M. Ziman

Course Title: Materials Science

Course Code	PHY91DE22503	**Credits**	3
L+T+P	3+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	45(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This main objective of this course to provide the deep understanding of materials science, how the properties of material associated to crystal structure. create understanding the composites, polymers and mechanical behavior of these materials in details. Describe and discuss novel technological important materials. This course aims to

1. To provide broad knowledge of the material properties, their utilization, and development of these properties to meet the requirements set by different applications.
2. To acquaint students about the development, properties and behaviour of metallic, ceramic, and polymeric materials under various conditions and in different applications.
3. To facilitate the understanding of manufacturing technologies and how they are used to affect properties and structure
4. Familiarize the student with new technological important materials and their properties.
5. This course should give the student confidence to undertake higher level education or job assignments in various institutes in India or in abroad.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Describe different materials at the structural level.
2. Explain mechanical and thermal properties of materials based on the inner structure.
3. Understand basic structure-property relationships.
4. Mathematically model for diffusion processes, creep, and corrosion behavior of materials
5. Understanding how to utilize material properties in practice, apply knowledge in materials selection

Course Contents:

Unit-1

Formation and structure of materials: Introduction to Materials Science- Engineering materials - structure - property relationship, Review of ionic, covalent and molecular bindings, bond angle, bond length and bond energy, lattice energy - Madelung constant cohesive energy, van der Waal's Interaction- Lennard- Jones Potential, closed packed structure-packing efficiency and density of materials. Crystal imperfections: Review of crystalline imperfection, Schottky and Frenkel defects- Equilibrium concentrations, edge and screw dislocations, surface imperfections. Introduction to Nanomaterials and their Properties

(35 % Weightage)

Unit-2

Elastics and plastics behavior of materials: Atomic model of elastic behavior-rubber like Elasticity- anelastic behavior, viscoelastic behavior, fracture of materials-Ductile and brittle fracture, protection against fracture Plastic deformation by slip-shear strength of perfect and real crystals- CRSS ratio, methods of strengthening crystalline materials against plastic deformation-strain hardening, solid solution strengthening, precipitation strengthening.

(25 % Weightage)

Unit-3

Composite materials: Classification of composite materials, matrix materials- polymer, metals, ceramics, reinforcing materials- fibers, particles, concrete-concrete making materials, structure, composition, properties and applications, application of polymer matrix composites, metal matrix composites, ceramic-matrix composites, carbon-fibre composites, fibre reinforce, particle reinforce composites with properties and applications. **Elements of polymer science**: Introduction to polymer, classifications of polymer, synthesis of polymers-chain polymerization, step polymerization, Industrial polymerization methods, Phase transition-Polymer melting and glass transition, stereo isomerism, degree of crystallinity.

(40 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Introduction to Materials Science- Engineering materials - structure - property relationship, Review of ionic, covalent and molecular bindings, bond angle
5-8	Bond length and bond energy, lattice energy - Madelung constant cohesive energy, van der Waal's Interaction- Lennard- Jones Potential, closed packed structure-packing efficiency and density of materials.
9-14	Crystal imperfections: Review of crystalline imperfection, Schottky and Frenkel defects- Equilibrium concentrations, edge and screw dislocations, surface imperfections.
15-17	Introduction to Nanomaterials and their Properties
17-20	Atomic model of elastic behavior-rubber like Elasticity- anelastic behavior, viscoelastic behavior
21-24	Fracture of materials-Ductile and brittle fracture, protection against fracture Plastic deformation by slip-shear strength of perfect and real crystals-CRSS ratio
25-30	Methods of strengthening crystalline materials against plastic deformation-strain hardening, solid solution strengthening, precipitation strengthening

31-32	Classification of composite materials, matrix materials- polymer, metals, ceramics,
33-36	Reinforcing materials- fibers, particles, concrete-concrete making materials, structure, composition, properties and application of polymer matrix composites, metal matrix composites, ceramic-matrix composites, carbon-fibre composites,
36-37	Fibre reinforce, particle reinforce composites with properties and applications applications,
38-39	Introduction to polymer, classifications of polymer,
40-42	Synthesis of polymers-chain polymerization, step polymerization, Industrial polymerization methods,
42-45	Phase transition-Polymer melting and glass transition, stereo isomerism, degree of crystallinity

Essential Readings:

1. Elements of Materials Science and Engineering: Lowrence H. Van Vlack, Addison Wesley,
2. Materials Science and Engineering W.D. Callister Wiley.
3. Polymer Science, V. R Gowariker, N.V. Vishwanathan, JoydevShreedhar, Wiley
4. Materials Science and Engineering, V. Ragharan, Prentice Hall
5. Foundations of Materials Science and Engineering-William F. Smith, McGraw Hills International Edition

Additional/Advance/Further Readings:

1. Introduction to Ceramics: W D Kingery, H K Bower and VR'uhlman, John Wiley
2. Structure and Properties of materials-vol I-IV Rose, Shepard and Wulff
3. Polymer Science, V. R Gowariker, N.V. Vishwanathan, JoydevShreedhar, Wiley Eastern,
4. Text of Polymer Science, Fred. W.Billmeyer, John Wiley and Sons, Inc.

Course Title: Alloy Design and Development

Course Code	PHY91DE22603	Credits	3
L+T+P	2+0+1	Course Duration	One Semester
Semester	III	Contact Hours	30(L)+ 15(P) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar, and Practical
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are

1. To provide broad knowledge of the Alloy Design and Development,
2. To acquaint students about the important Alloys
3. To facilitate the understanding of Alloy Design and development of alloys at Laboratory.
4. To generate the skill for synthesis of nanoparticles.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. have knowledge about the basic concept of alloys and its properties
2. impart the importance of overall design in metallurgy. .
3. understand all newer types of alloys and its applications
4. The physical metallurgy, of different metal elements
5. attain sound knowledge on microstructures, properties, and applications of several alloys.
6. Design of different alloys for specific applications

Course Contents:

Unit-1

Concept and of alloy design, Steps in alloy design, Significance of alloy design. Single phase, dual phase and multiphase materials, Effect of size, shape and distribution of second phase on mechanical and magnetic properties of alloys. Precipitation and particle coarsening, recrystallization and grain growth. Solid/Liquid phase transformation in pure metals, single phase alloys, constitutional super cooling and eutectic alloys.

(35 % Weightage)

Unit-2

Standards in alloy steels – Study of a few selected standards.Quasicrystalline alloys, Alloy steel design for better tensile strength, ductility, toughness, fatigue strength, creep strength, wear resistance and elevated temperature strength.Alloy design of lightweight, high strength, corrosion resistance Non Ferrous alloys, Magnetic alloys, Multicomponent alloys and their Applications. Different synthesis routes and their effect on properties of Alloys.

(40 % Weightage)

Unit-3

Practical; *Experiments on following aspects of Alloys* 1.Synthesis of alloys through different synthesis routes e.g mechanical alloying, solid state synthesis, arc melting, induction melting etc. 2. Effect annealing temperature and conditions, on phase revolution and properties of different alloys.3. Mechanical Magnetic and corrosion behaviors of different alloys *Experiments will be decided with above reference based on the facility available

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Introduction to nanomaterials Size Dependent properties. Bulk to Nano Transitions.
6-10	Method of Synthesis: Thermal and ultrasound decomposition methods. Reduction methods. Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductor nanoparticles. High energy ball milling and mechanical attrition. Thermal evaporation. Sputtering. Laser ablation. Chemical vapour deposition. Molecular beamepitaxy. Thermal spraying. Electro and electroless deposition.
11-15	Brief description of OD,1D,2Dnanomaterials e.g. Quantum wells, wires and dots. Size and dimensionality effects. Excitons. Single electrontunneling. Applications in infrared detectors and quantum dot lasers. Magnetic properties of nanocrystalline materials. Nanostructured ferroelectric materials and their properties.
16-20	Carbon Nanostructures: Nature of Carbon Clusters, Discovery of C60, Structure of C60 and its Crystal, Superconductivity in C60, Carbon Nanotubes:
20-22	Synthesis, Structure, Electrical and Mechanical
23-26	Properties; Graphene: Discovery, Synthesis and Structural Characterization through TEM, Elementary Concept of its applications. Properties of carbon nanotubes.
27-30	Inorganic nanotubes and nanorods, nanoporous materials.

Essential Readings:

1. Structure and Properties of Alloys – Robert M. Brick, Robet B. Gordon & Arthur Phillips, Eurasia Publishing House (private) Ltd., New

2. Ranganathan S., Arunachalam V.S. and Cahn R.W. (Eds.), Alloy Design, Indian Academy of Science, Bangalore,1981

3. Materials Science and Engineering, V. Ragharan, Prentice Hall (1993).
4. Tien John K. and Ansell George S. (Eds.), Alloy and Micro structural Design, Academic Press.

Additional/Advance/Further Readings:

1. Materials Science and Engineering W.D. Callister Wiley.

Course Title: Fundamentals of Scanning Probe Microscopy

Course Code	PHY91DE22703	**Credits**	3
L+T+P	3+0+0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	45(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

Following are the main objectives of this course:

1. to present a unified discussion of the fundamentals of atomic force microscopy and scanning tunneling microscopy
2. To acquaint the students with the instrumental aspects and basics like the tip-sample interaction, contact mechanics etc.
3. To introduce several specialized techniques based on atomic force microscopy and scanning tunneling microscopy

Course Learning Outcomes:

Upon completion of this course, the student should:

1. understand the basic aspects of tip-surface interactions in contact and non-contact regime.
2. be able to describe the basic components necessary to build a basic AFM instrument and carry out contact mode imaging.
3. understand the interactions of an oscillating probe with the surface as in dynamic AFM.
4. comprehend the methodology of using dynamic AFM for measuring electric and magnetic forces on the surface and in liquid medium.
5. understand the basic concepts of quantum tunneling and its application in imaging and manipulation at the surface with atomic resolution.

Course Contents:

Unit-1: Tip-Surface Interaction

Non-contact regime Intra-molecular Interactions, Electric Dipoles, Inter-molecular interactions: Physical models, ion-dipoles, Keesom forces, Dispersion Force

Contact regime Hamaker theory, surface energies, Dejaugin approximation, contact mechanics, Hertz model, JKR model, DMT model

(20 % Weightage)

Unit-2: Atomic Force Microscope (AFM)

AFM components, AFM calibration, Contact Mode Scans Force Spectroscopy Cantilever mechanics, Approach-retract curves, Processing Force curves, Modulus and adhesion Maps, Lateral Force Microscopy Conducting Atomic Force Microscopy, Nano-indentation

(20 % Weightage)

Unit-3: Dynamic AFM methods

Point Mass Model of Dynamic AFM, frequency response, conservative and dissipative interaction forces, interacting with the surface Analytical theory of Dynamic AFM : Excited probe interacting with sample (linear theory), Amplitude and Frequency modulation AFM, Non-linear/dissipative interactions, Attractive and Repulsive Regimes and Phase Contrast Modualtion AFM

Reconstructing Surface Forces: Relationship between Frequency shift and Potential Energy, reconstruction of interaction force from frequency shift in FM-AFM, Experimental details of FM-AFM measurements

(20 % Weightage)

Unit-4: Dynamic AFM for Electrostatics/Magnetic/Biology

Measuring Electrostatic Forces, Measuring Magnetic Forces, Dynamic AFM in Liquids Specialized dynamic-AFM based techniques for physical property measurements: Piezo-response force microscopy, Scanning non-linear dielectric microscopy, Magnetic exchange force microscopy

(20 % Weightage)

Unit-5: Scanning Tunneling Microscopy

Quantum tunneling, WKB approximation for field emission, STM instruments and its components, Scanning tunneling spectroscopy, Inelastic electron tunneling spectroscopy Atomic/molecular manipulations, spin-polarized STM, radio-frequency STM

(20 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Tip-sample interactions in non-contact regime
7-12	Tip-sample interactions in contact regime
13-16	AFM components, AFM calibration, Contact Mode Scans
17-20	Force Spectroscopy, Cantilever mechanics, Approach-retract curves, Processing Force curves, Modulus and adhesion Maps, Lateral Force Microscopy
21-24	Conducting atomic force microscopy, Nano-indentation

25-28	Point Mass Model of Dynamic AFM, frequency response, conservative and dissipative interaction forces, interacting with the surface
29-32	Analytical theory of Dynamic AFM : Excited probe interacting with sample (linear theory), Amplitude and Frequency modulation AFM, Non-linear/dissipative interactions, Attractive and Repulsive Regimes and Phase Contrast Modualtion AFM
33-36	Relationship between Frequency shift and Potential Energy, reconstruction of interaction force from frequency shift in FM-AFM, Experimental details of FM-AFM measurements
37-38	Measuring Electrostatic Forces
39-40	Measuring Magnetic Forces
41-42	Dynamic AFM in Liquids
43-48	Special AFM techniques: Piezo response force microscopy (PFM), Scanning non-linear dielectric microscopy (SNDM), Magnetic exchange force microscopy
49-60	Scanning Tunneling Microscoopy, STM instruments and its components, Scanning tunneling spectroscopy, Inelastic electron tunneling spectroscopy, Atomic/molecular manipulations, spin-polarized STM, radio-frequency STM

Essential Readings:

1. Wiesendanger, R., Scanning Probe Microscopy and Spectroscopy: Methods and Applications, Cambridge University Press, 1994.

2. Israelachvili, J. N., Intermolecular and Surface Forces, Third Edition, Elsevier

Additional/Advance/Further Readings:

1. Fundamentals of Scanning Probe Microscopy, V. L. Mironov, The Russian Academy of Sciences, Institute for Physics of Microstructures, 2004

2. Scanning Probe Microscopy: Electrical and Electromechanical Phenomena at the Nanoscale, Sergei V. Kalinin, Alex Gruverman, Springer-Verlag New York, 2007.

3. Springer Handbook of Nanotechnology, Ed. Bharat Bhushan, Springer-Verlag Berlin Heidelberg, 2010

Course Title: Low Temperature Physics

Course Code	PHY92DE22804	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

1. To understand that physical phenomena are often studied at low temperature, particularly within condensed matter physics.
2. To understand properties of superfluid helium and Bose-Einstein condensates, i.e. of macroscopic quantum fluids.
3. To gain knowledge of different cooling methods, thermal properties of materials, thermometry, etc.
4. The course is suitable for those that want to do research in Physics.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. describe the phase diagrams for both helium-3 and helium-4.
2. describe how Bose-Einstein condensation comes about.
3. describe superfluid phenomena such as, rollin film, the fountain effect and second sound.
4. describe different cooling methods which are used both above and below 1 Kelvin.
5. explain physical properties of different materials at low temperature.

Course Contents:

Unit-1

(20 % Weightage) PRODUCTION OF LOW TEMPERATURE Introduction - Joule Thomson effect - Regenerative cooling - Vacuum pumps - liquefaction of air - Hydrogen - Helium - Maintenance of low temperature - production of temperature below 1 K - Adiabatic demagnetization - Evaporative cooling of He-3 - Dilution refrigeration - Laser cooling - Nuclear demagnetization.

Unit-2

MEASUREMENT OF LOW TEMPERATURE : The gas thermometer and it corrections - Secondary thermometers - resistance thermometers, thermocouples - vapour pressure thermometers - magnetic thermometers. (20 % Weightage)

Unit-3

LIQUID AND SOLID CRYOGENS Liquid Nitrogen - Liquid oxygen - Liquid hydrogen - Liquid He-4 and He-3 - Solid He - 4 and He -3 - Lamda point - Superfluidity - Density - Compressibility factor - viscosity and thermal properties - Velocity of sound in liquid helium.

(20 % Weightage)

Unit-4

ELECTRICAL AND MAGNETIC PROPERTIES Experimental Observations - Theories of sommerfield and block - Superconductivity - magnetic properties of superconductors - Thermal properties of superconductors - penetration depth and high frequency resistance - Ferromagnetism - Diamagnetism - paramagnetism - Paramagnetic saturation.

(20 % Weightage)

Unit-5

SPECIFIC HEATS, SPECTROSCOPIC AND HYPERFINE PROPERTIES Specific heats - Rotational specific heat of Hydrogen - Einstein's and Debye's theories Schottky effect - Anomalies in specific heats at low temperature - Infrared - visible spectra - Zeeman spectra at low temperature - Dielectric constant and its measurement - Magnetic susceptibility - NMR and electron paramagnetic resonance at low temperature - Nuclear magnetic properties - Mossbauer effect and other hyperfine properties at low temperature.

(20 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Introduction - Joule Thomson effect - Regenerative cooling - Vacuum pumps - liquefaction of air- Hydrogen - Helium
7-12	Maintenance of low temperature -production of temperature below 1 K -Adiabatic demagnetization - Evaporative cooling of He-3 - Dilution refrigeration- Laser cooling- Nuclear demagnetization
13-18	The gas thermometer and it corrections - Secondary thermometers
19-24	resistance thermometers, thermocouples- vapour pressure thermometers- magnetic thermometers
25-30	Liquid Nitrogen - Liquid oxygen - Liquid hydrogen - Liquid He -4 and He -3 - Solid He– 4 and He -3 - Lamda point
31-36	Superfluidity - Density - Compressibility factor - viscosity and thermal properties - Velocity of sound in liquid helium
37-40	Experimental observations - Theories of sommerfield and block
41-44	Superconductivity - magnetic properties of superconductors - Thermal properties of superconductors - penetration depth and high frequency resistance
45-48	Ferromagnetism - Diamagnetism - paramagnetism – Paramagnetic saturation

49-52	Specific heats - Rotational specific heat of Hydrogen - Einstein's and Debye's theories Schottky effect - Anomalies in specific heats at low temperature - Infrared- visible spectra -
53-56	Zeeman spectra at low temperature - Dielectric constant and its measurement – Magnetic susceptibility - NMR and electron paramagnetic resonance at low temperature
57-60	Nuclear magnetic properties - Mossbauer effect and other hyperfine properties at low temperature

Essential Readings:

1. Cornelis Jacobus Gorter, D. F. Brewer, Progress in Low Temperature Physics, Elsevier Ltd, 2011.
2. Christian E. and Siegfried H, Low Temperature Physics, Springer, 2005.

Additional/Advance/Further Readings:

1. Jack Ekin, Experimental Techniques for Low-Temperature Measurements, OUP Oxford, 2006.
2. Charles P. Poole Jr., Horacio A. Farach, Richard J. Creswick and RuslanProzorov,Superconductivity Elsevier Ltd, 2007.
3. John Wilks, Properties of Liquid and Solid Helium, Oxford University Press, 1967.
4. Jackson L.C., Low Temperature Physics, Methuen and Company,1962.
5. Ching Wu Chu and J.Woollam, High Pressure and Low Temperature Physics, Plenum Press, 1978.

Course Title: Ancient Indian Sciences

Course Code	PHY92OE22904	Credits	4
L+T+P	4+0+0	Course Duration	One Semester
Semester	IV	Contact Hours	60(L) Hours

Course Type	Open Elective (Interdisciplinary) Course
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Enhancement, Value Addition, Indian Knowledge Systems
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment 2. 70% - End Term Examination

Course Objectives:

The main objective of this course is to introduce the indian worldview about different worldly phenomena and to analyse them comparatively with the modern scientific understanding.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. understand the basic concepts behind the terminologies used in ancient texts.
2. have a critical thinking on different scientific works in ancient texts.
3. research further in the field.

Course Contents:

Unit-1

Ancient Indian Mathematics: Definition of GaNita; Importance and all pervading nature of GaNita; Prescriptive nature of GaNita; Concept of zero; Decimal System; Arithmetics; Algebra; Negative numbers; Trigonometry; GaNita in Vedaangas; Early Geometry; Concept of etc.; Shulba-Sootra - Geometrical Calculations; GaNita Jyotisha; GaNita in prosody; GaNita in language; GaNita in music (Hemchandra Series); Binary system; Permutations and Combinations; Kerala school; Early Calculus; Upapatti - Indian version of proof; Similarities and contrast from modern mathematics, Vedanta and the number system. (10 Lectures)

Unit-2

Ancient Indian Astronomy: Jyotisha - the science of time-keeping; Importance of Jyotisha; GaNita Jyotisha; Panchaanga; Phalita Jyotisha; Phalita Jyotisha and the causal nature of universe; works of different ancient scientists in the field of Jyotisha

(10 Lectures)

Unit-3

Physics: Use of GaNita as prescription in contrast to use of mathematics as description; Motion; Gravitation; Concept of Paramaanu - Vaisheshik darshana; Syaatvaada and probabilistic interpretation of quantum mechanics; Cosmology; Causality; Physics in Jain and Bauddha darshana; HetvABHAsa and its relevance in policy making of Indian science (10 Lectures)

Unit-4

The science of Language: Meaning of Bhasha; Evolution of language; Praakrita and Sanskrita; Grammar of Sanskrita - Ashtadhyaayii by Paaninii; Sanskrit as world's most mathematical human language; Sanskrit for technical discourse; Basic knowledge of Sanskrita (Dhaatu, Pratyaya, Vibhakti, Vachana, Linga, Purusha; Lakaara, Sandhi, Samaasa); Order of words in Sanskrita; Rules to make new words; Falsification of word-to-word translation; Language as vehicle of culture and civilisation; Science in Sanskrita literature (10 Lectures)

Unit-5

The science of well-being: Definition of Ayurveda; Swaasthya in contrast to health; Importance of being healthy; Ayurveda as a way of life; Vaata, Pitta, Kapha; Quality of a good medicine; Yoga and Praanaayaama - definition and its importance as a method for well-being; Air, Water, Soil, Oil, Ghee, Cloth as a tool to heal; Mantra-healing; Surgery in ancient India; Healthy diet; Indian kitchen - a medicine store; Contribution of homemaking women in evolution of Ayurveda (10 Lectures)

Unit-6

Social and Economic Sciences: Expansion of self as family; Human body as a prototype of social structure; Family as a prototype for social administration; Gandhi's idea of Swaraajya; Sharing as a way of life; Economic system based on sharing; Sanskaaras - Prescription for proper distribution; Jaati as an economical unit; Village as an independent economic unit; Arthashaastra; Concept of virtual money in today's world and its absence in ancient Indian economic systems; Evolution of modern economic system based on virtual money, banks and markets; Comparative study of modern economic system with the ancient one; The Angus Maddison report (10 Lectures)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-10	Ancient Indian Mathematics
11-20	Ancient Indian Astronomy
21-30	Physics in Ancient India
31-40	The science of Language
41-50	The science of well-being
51-60	Social and Economic Sciences

Essential Readings:

1. Indian Science and Technology in the Eighteenth Century: Some Contemporary European Accounts - Dharampal; Other India Press

2. Science in Samskrita; Samskrita Bharati
3. Pride of India: A glimpse into India's scientific heritage; Samskrita Bharati

Additional/Advance/Further Readings:

1. The History of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited
2. The golden age of Indian mathematics - S Parameswaran; Swadeshi Science Movement Kerala
3. The Wonder that is Sanskrit - Sampad & Vijay; Auro Publications

Course Title: Renewable Energy: Solar and Hydrogen

Course Code	PHY92DE23004	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are

1. Understand the various forms of conventional energy resources.
2. Learn the present energy scenario and the need for energy conservation
3. Explain the concept of various forms of renewable energy
4. Outline division aspects and utilization of renewable energy sources for both domestics and industrial application.
5. Analyze the environmental aspects of renewable energy resources.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Describe the environmental aspects of non-conventional energy resources.
2. Know the need of renewable energy resources, historical and latest developments. Describe the use of solar energy.
3. Understand the concept of Hydrogen energy and economy.
4. Acquire the knowledge of fuel cells, wave power, tidal power and geothermal principles and applications.

Course Contents:

Unit-1

Solar Energy: Fundamental and Material Aspects:Fundamentals of photovoltaic Energy Conversion Physics and Material Properties, Basic to Photovoltaic Energy Conversion: Optical properties of Solids. Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.

(25 % Weightage)

Unit-2

Solar Energy: Different Types of Solar Cells: Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current, Brief description of single crystal silicon and organic and Polymer Solar Cells, Elementary Ideas of Advanced Solar Cells e.g. Tandem Solar cells, Solid Liquid Junction Solar Cells, Nature of Semiconductor, Principles of PhotoelectrochemicalSolar Cells.

(25 % Weightage)

Unit-3

Hydrogen Energy: Fundamentals, Production and Storage: Relevance in relation to depletion of fossil fuels and environmental considerations. Solar Hydrogen through Photoelectrolysis, Physics of material characteristics for production of Solar Hydrogen. Brief discussion of various storage processes, special features of solid hydrogen storage materials, Structural and electronic characteristics of storage materials.New Storage Modes.

(25 % Weightage)

Unit-4

Hydrogen Energy: Safety and Utilization: Various factors relevant to safety, use of Hydrogen as Fuel, Use in Vehicular transport, Hydrogen for Electricity Generation, Fuel Cells, Various type of Fuel Cells, Applications of Fuel Cell, Elementary concepts of other Hydrogen- Based devices such as Hydride Batteries.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Fundamentals of photovoltaic Energy Conversion Physics and Material Properties,
6-10	Basic to Photovoltaic Energy Conversion: Optical properties of Solids
11-15	Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.
16-20	Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current,
20-22	Description of single crystal silicon and organic and Polymer Solar Cells,
23-26	Elementary Ideas of Advanced Solar Cells e.g. Tandem Solar cells, Solid Liquid Junction Solar Cells, Nature of Semiconductor,
27-30	Principles of Photoelectrochemical Solar Cells.
31-35	Relevance in relation to depletion of fossil fuels and environmental considerations. Solar Hydrogen through Photoelectrolysis,
36-40	Physics of material characteristics for production of Solar Hydrogen. Brief discussion of various storage processes,
41-45	special features of solid hydrogen storage materials, Structural and electronic characteristics of storage materials. New Storage Modes.
46-50	Various factors relevant to safety, use of Hydrogen as Fuel, Use in Vehicular transport, Hydrogen for Electricity Generation, Fuel Cells,
50-55	Various type of Fuel Cells, Applications of Fuel Cell,
56-60	Elementary concepts of other Hydrogen- Based devices such as Hybrid Batteries.

Essential Readings:

1. Solar Cell Devices-Physics :Fonash
2. Fundamentals of Solar Cells Photovoltaic Solar Energy :Fahrenbruch& Bube
3. Phoptoelectrochemical Solar Cells: Chandra
4. Hydrogen as an Energy Carrier Technologies Systems Economy : Winter & Nitch (Eds.)

Additional/Advance/Further Readings:

1. Hydrogen as a Future Engery Carrier : Andreas Zuttel, Andreas Borgschulte and Louis Schlapbach
2. Hydrogen Storage Technologies Mehmet Sankir, Nurdan Demirci Sankir John Wiley and Sons

Course Title: Nanoscience and Nanotechnology

Course Code	PHY92DE23104	Credits	4
L+T+P	3+0+1	Course Duration	One Semester
Semester	IV	Contact Hours	45(L) + 15(P) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objectives of this course are

1. To provide broad knowledge of Nanostructures.
2. To acquaint students about the important Carbon based Nanostructures and Their Applications
3. To acquaint students about the important nanoparticles different nanostructures and their applications
4. To facilitate the understanding of synthesis of Carbon based Nanostructures.
5. To generate the skill for synthesis of nanoparticles.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. have knowledge about the basic concept of nanomaterterials
2. impart the importance of overall design of carbon based nanomaterials.
3. understand advanced nanostructres
4. attain sound knowledge on microstructures, properties, and applications of different nanostructures.
5. design different carbon based nanostructures.
6. develop new materials and which can be useful in new technologies.

Course Contents:

Unit-1

Introduction to nanomaterials Size Dependent properties.Bulk to Nano Transitions. Method of Synthesis: Thermal and ultrasound decomposition methods. Reduction methods.Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductornanoparticles. High energy ball milling and mechanical attrition.Thermal evaporation. Sputtering.Laser ablation. Chemical vapour deposition. Molecular beamepitaxy. Thermal spraying.Electro and electroless deposition.Brief description of OD,1D,2D nanomaterials e.g. Quantum wells, wires and dots. Size and dimensionality effects.Excitons.Single electron tunneling. Applications in infrared detectors and quantum dot lasers.Magnetic properties of nanocrystalline materials.Nanostructured ferroelectric materials and their properties.

(35 % Weightage)

Unit-2

Carbon Nanostructures: Nature of Carbon Clusters, Discovery of C60, Structure of C60 and its Crystal, Superconductivity in C60, Carbon Nanotubes: Synthesis, Structure, Electrical and Mechanical Properties. Graphene: Discovery, Synthesis and Structural Characterization through TEM, Elementary Concept of its applications. Properties of carbon nanotubes. Inorganic nanotubes and nanorods, nanoporous materials.

(40 % Weightage)

Unit-3

*Practical 1. Synthesis of nanomaterials through different methodsMecahnical-milling, Sol-gel and other synthesis methods 2. Characterizations of nanomaterial through XRD TEM SEM AFM and other techniques.3. Synthesis of Carbon Nanotubes through CVD. 4.Characterizations through XRD TEM. 5. ynthesis of Graphene through different methods. 6. Characterizations through XRD TEM. 8. Different properties of carbon nanostructures. *Experiments will be decided with above reference based on the facility available

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Introduction to nanomaterials Size Dependent properties. Bulk to Nano Transitions.
6-10	Method of Synthesis: Thermal and ultrasound decomposition methods. Reduction methods. Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductor nanoparticles. High energy ball milling and mechanical attrition. Thermal evaporation. Sputtering. Laser ablation. Chemical vapour deposition. Molecular beamepitaxy. Thermal spraying. Electro and electroless deposition.
11-15	Brief description of OD,1D,2Dnanomaterials e.g. Quantum wells, wires and dots. Size and dimensionality effects. Excitons. Single electrontunneling. Applications in infrared detectors and quantum dot lasers. Magnetic properties of nanocrystalline materials. Nanostructured ferroelectric materials and their properties.
16-20	Carbon Nanostructures: Nature of Carbon Clusters, Discovery of C60, Structure of C60 and its Crystal, Superconductivity in C60, Carbon Nanotubes:
20-22	Synthesis, Structure, Electrical and Mechanical

23-26	Properties; Graphene: Discovery, Synthesis and Structural Characterization through TEM, Elementary Concept of its applications. Properties of carbon nanotubes.
27-30	Inorganic nanotubes and nanorods, nanoporous materials.

Essential Readings:

1. Introduction to Nanotechnology: Poole and Owners
2. Nano Essentials: T. Pradeep
3. Handbook of Nanostructured Materials and Nanotechnology : Nalva
4. Nano Technology/ Principles and Practices: S.K. Kulkarni

Additional/Advance/Further Readings:

1. Quantum Dots : Jacak, Hawrylak and Wojs
2. Carbon Nanotubes: SilvanaFiorito 6. Nanotechlongy: Richard Booker and Earl Boysen

Course Title: Physics of Magnetism and Spintronics

Course Code	PHY92DE23204	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

This course aims to

1. To know the basic science of magnetism and visualize the applications.
2. To understand the theory of magnetization dynamics and the necessity magnetic anisotropy.
3. To know MCE at the first order & second order phase transitions for refrigeration applications.
4. To know Physics of different kind of thin films/coating.

Course Learning Outcomes:

Upon completion of this course, the student should able to :

1. Explain the fundamentals of magnetism by molecular field theory and band theory.
2. Apply solid state physics to appreciate domain wall mechanism.
3. Analyze the magnetization dynamics through various characterization techniques.
4. Interpret the physical origin of magnetic anisotropy and its effects.
5. Evaluate the magnetostriction for various single and polycrystalline materials.
6. Recall the mechanism of Magnetocalorics and Magnetoelectronics.
7. Having a clear understanding of the subject related concepts and of contemporary issues.
8. Having critical thinking and innovative skills.

Course Contents:

Unit-1

Magnetism in metals: Free electron model, Pauli paramagnetic, Spontaneously spin-split bands, Landau levels,Landau diamagnetism, Magnetism of the electron gas, Excitations in the electron gas, Spin density waves, Kondo effect. Magnetic anisotropy: Shape anisotropy, Magneto-crystalline anisotropy and its origin, Induced anisotropy Competing interactions and low dimensionality: Magnetic frustration, Spin glasses, Superparamagnetic, One and two-dimensional magnets.

(25 % Weightage)

Unit-2

Introduction- overview of development of Spintronics and its future scope, Magnetic multilayers, Magnetic Anisotropy of thin films, Interlayer Exchange Coupling and Exchange Bias, Spin dependent transport - Anisotropic magnetoresistance, Giant Magneto Resistance (GMR) effect - Phenomenological theory, Microscopic theory for current in plane (CIP) and current perpendicular to plane (CPP) GMR, Effects of spin-flip scattering Spin tunneling, Tunnel Magnetoresistance (TMR), Effects of Fermi surface, Effect of interfacial states, diffusive tunneling, Spin flip tunneling, Bias voltage dependence of TMR, Magnetic tunnel Junctions (MTJ), Tunnel Junctions with Half Metals

(25 % Weightage)

Unit-3

Introduction to thin films, Technology as a drive and vice versa, Basics of vacuum science and technology, Vacuum pumps and gauges. Physical vapor deposition, Raoult's law of evaporation, evaporation rate, evaporation of elements, compounds and alloys, Hertz Knudsen equation; Knudsen cell, Film Thickness Uniformity and Purity

(25 % Weightage)

Unit-4

Molecular beam epitaxy (effusion cell, growth rate, growth of GaAs/AlGAs and GSMBE), Role of Kinetics of Adsorption and Desorption, Surface reconstruction, In-situ film characterization of MBE films by LEED and RHEED, & RHEED Oscillations, Pulsed Laser deposition (PLD process steps, congruent evaporation, advantages and disadvantages of PLD). CVD advantages, CVD Reaction types, Thermodynamics of CVD, Gas Transport, Viscous flow, Close-Spaced Vapor Transport (CSVT), Convection, Film Growth Kinetics, Axial and radial film thickness uniformity, Classification of CVD systems, APCVD, LPCVD & MOCVD and Examples of CVD growth.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Free electron model, Pauli paramagnetic, Spontaneously spin-split bands,
5-8	Landau levels,Landau diamagnetism, Magnetism of the electron gas, Excitations in the electron gas,
9-12	Spin density waves, Kondo effect. Magnetic anisotropy: Shape anisotropy, Magneto-crystalline anisotropy and its origin,
13-16	Induced anisotropy Competing interactions and low dimensionality: Magnetic frustration, Spin glasses, Superparamagnetic, One and two-dimensional magnets.

17-20	Introduction- overview of development of Spintronics and its future scope, Magnetic multilayers, Magnetic Anisotropy of thin films,
21-24	Interlayer Exchange Coupling and Exchange Bias, Spin dependent transport - Anisotropic magnetoresistance, Giant Magneto Resistance (GMR) effect - Phenomenological theory,
25-28	Microscopic theory for current in plane (CIP) and current perpendicular to plane (CPP) GMR, Effects of spin-flip scattering Spin tunneling, Tunnel Magnetoresistance (TMR), Effects of Fermi surface, Effect of interfacial states, diffusive tunneling,
28-32	Spin flip tunneling, Bias voltage dependence of TMR, Magnetic tunnel Junctions (MTJ), Tunnel Junctions with Half Metals.
32-36	Introduction to thin films, Technology as a drive and vice versa, Basics of vacuum science and technology, Vacuum pumps and gauges.,
36-40	Physical vapor deposition, Raoult's law of evaporation, evaporation rate, evaporation of elements, compounds and alloys,
41-44	Hertz Knudsen equation; Knudsen cell, Film Thickness Uniformity and Purity,
45-48	Molecular beam epitaxy (effusion cell, growth rate, growth of GaAs/AlGAs and GSMBE), Role of Kinetics of Adsorption and Desorption,
49-52	Surface reconstruction, In-situ film characterization of MBE films by LEED and RHEED, & RHEED Oscillations, Pulsed Laser deposition (PLD process steps, congruent evaporation,
53-56	advantages and disadvantages of PLD). CVD advantages, CVD Reaction types, Thermodynamics of CVD, Gas Transport, Viscous flow, Close-Spaced Vapor Transport (CSVT), Convection,
57-60	Film Growth Kinetics, Axial and radial film thickness uniformity, Classification of CVD systems, APCVD, LPCVD & MOCVD and Examples of CVD growth.

Essential Readings:

1. Magnetism in Condensed Matter, 1st edition, Oxford University Press, 2001-S. Blundell
2. Modern Magnetic Materials, John Wiley & Sons, Inc., 2000-R. C. O' Handley.
3. Nanomagnetism and Spintronics, 1st edition, Elsevier, 2009-3. T. Shinjo (Ed.).
4. Handbook of Spin Transport and Magnetism, CRC Press, 2012-4. E. Y. Tsymbal and I Zutic.

Additional/Advance/Further Readings:

1. Materials Science of Thin Films Deposition and Structure-Milton Ohring.
2. Thin Film Solar Cells-Chopra and Das.

Course Title: Nanoelectronics

Course Code	PHY92DE23304	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

Following are the main objectives of this course:

1. To acquaint the students about the miniaturization driven progress in electronics
2. To acquaint the students with the failure of classical models to describe behavior of devices at nanometer length scale.
3. To introduce a theory of current, voltage, and resistance from atoms up.
4. To familiarize the student with the electronic properties of molecules, carbon nanotubes, crystals.
5. To acquaint the students with the theory of energy band formation and the origin of metals, insulators, and semiconductors.
6. To acquaint the students with a theory of electron conduction beginning with ballistic transport and concluding with a derivation of Ohm's law.
7. To acquaint the students about how to go from ballistic to bulk MOSFET devices.
8. To orient the student with the basics of nano-fabrication techniques.

Course Learning Outcomes:

Upon completion of this course, the student should:

1. To describe the Moore's law
2. To describe the impact of nanotechnology
3. To describe the experimental observables in a mesoscopic system.
4. To describe the basics properties of new types of molecular materials used in devices.
5. To calculate the density of states of model 0D, 1D, 2D and 3D materials.

6. To describe the basic concepts of HOMO and LUMO
7. To calculate the conductance in a two terminal quantum device.
8. To calculate the conductance in ballistic FETs.
9. To describe the basic nanofabrication techniques.

Course Contents:

Unit-1

Introduction to Nanoelectronics, Device scaling, Moore's law, limitations, role of quantum mechanics, Nanostructures: Impact, technology and physical consideration;
Mesoscopic observables: Ballistic transport, phase interference, universal conductance fluctuations, weak localization; Carrier heating.
Novel molecules (Pentacene, carbon nanotube, Fullerenes and its derivatives etc.) and conjugated polymers (Polyacetylene, P3HT, PEDOT:PSS etc.).

(25 % Weightage)

Unit-2

Preliminaries : Basic Quantum mechanics and Fermi statistics, Metals, Insulators and Semiconductor, Density of states (DOS) in 0D, 1 D, 2D and 3D, DOS in disordered materials,
Physics of organic semiconductors: concept of HOMO and LUMO, band gap.

(25 % Weightage)

Unit-3

Two terminal quantum dot and quantum wire devices: Equilibrium in two terminal devices, Current flow in the presence of a bias, numerical technique for self-consistent estimation of V-I ,
Current flow, quantum of conductance, Landauer theory;
Field Effect Transistors (FETs): Ballistic quantum wire FETs, conventional MOSFETs, CMOS, short channel and narrow width, hot electron effect, punch-through and thin gate oxide breakdown, OFET;
Spintronics: Spin, propagation, detection, spinFETs. (25 % Weightage)

Unit-4

Nano-fabrication techniques: Top-down and bottom-up strategies, advantages/disadvantages/ limitations, e-beam lithography, Focussed Ion beam milling, self-organized structures, laser nanopatterning, nano-imprint, electrochemical synthesis, Fabrication of organic electronic devices (OEDs) etc.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Introduction to Nanoelectronics, Device scaling, Moore's law, limitations, role of quantum mechanics
5-6	Nanostructures: Impact, technology and physical consideration;
7-13	Mesoscopic observables: Ballistic transport, phase interference, universal conductance fluctuations, weak localization; Carrier heating.

14-15	Novel molecules (Pentacene, carbon nanotube, Fullerenes and its derivatives etc.) and conjugated polymers (Polyacetylene, P3HT, PEDOT:PSS etc.)
16-19	Preliminaries : Basic Quantum mechanics and Fermi statistics, Metals, Insulators and Semiconductor
20-26	Density of states (DOS) in 0D, 1 D, 2D and 3D, DOS in disordered materials
27-30	Physics of organic semiconductors: concept of HOMO and LUMO, band gap
31-35	Two terminal quantum dot and quantum wire devices: Equilibrium in two terminal devices, Current flow in the presence of a bias, numerical technique for self-consistent estimation of V-I
36-38	Current flow, quantum of conductance, Landauer theory;
39-43	Field Effect Transistors (FETs): Ballistic quantum wire FETs, conventional MOSFETs, CMOS, short channel and narrow width, hot electron effect, punch-through and thin gate oxide breakdown, OFET;
44-45	Spintronics: Spin, propagation, detection, spinFETs.
46-49	Nano-fabrication techniques: Top-down and bottom-up strategies, advantages/disadvantages/ limitations
50-60	e-beam lithography, Focussed ion beam milling, laser nanopattering, nanoimprint, electrochemical synthesis, self-organized nanostructures.

Essential Readings:

1. Datta, S., Quantum Transport: Atom to Transistor; First Edition, Cambridge University Press (2005).
2. Atkins, P.W. and Friedman, R.S., Molecular Quantum Mechanics; Oxford University Press, 3rd edition (1997).
3. Lundstrom, M. and Guo J., Nanoscale Transistors; Physics, Modeling, and Simulation, First Edition, Springer (2006).
4. M. Stepanova and S. Dew, Nanofabrication: Techniques and Principles; Springer-Verlag (2012).

Additional/Advance/Further Readings:

1. M. Baldo, Introduction to Nanoelectronics (Lecture Notes; May 2011 MIT)
2. S. Datta, Electronic Transport in Mesocopic Systems; Cambridge University Press (1995).
3. David Ferry , Transport in Nanostructures Cambridge University Press (1995)

Course Title: Statistical Analysis Techniques in Nuclear and Particle Physics

Course Code	PHY92DE23404	**Credits**	4
L+T+P	4+0+0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	60(L) Hours

Course Type	Discipline Based Elective
Nature of the Course	Theory
Special Nature/ Category of the Course (if applicable)	Skill Based Core Elective
Methods of Content Interaction	Lecture, Tutorials, Group discussion; Self-study, Seminar
Assessment and Evaluation	1. 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 2. 70% - End Term External Examination (University Examination)

Course Objectives:

The main objective of this course is to introduce the students to the statistical analysis in Nuclear and Particle Physics. The objectives of this course are :

1. To give an insight about several distribution.
2. To provide students with an understanding of the nature of probability distribution.
3. To allow the students to become familiar with error estimations.
4. To introduce Bayes theorem.
5. To acquaint the students with hypothesis tests and discoveries Level.
6. To acquaint the students with artificial Neural Network and Boosted Decision Trees.
7. To orient the student Monte Carlo Monte Carlo technique

Course Learning Outcomes:

After completion of the course the learners will be able :

1. to understand the basic probability and various distribution.
2. to describe the random Errors, error propagation, and systematic errors.
3. comprehend basic maximum likelihood and Bayesian inference.
4. understand the Two-dimensional uncertainty contours.
5. understand the least square fitting,and binned data fitting.
6. understand the hypothesis tests and discoveries level
7. to describe the Random Number generator, and Monte Carle technique.

Course Contents:

Unit-1

Probability theory: Classical probability, Frequentist probability, Subjective (Bayesian) probability, Komogorov axiomatic approach, Probability distributions, PDFs in more dimensions, Mean, variance and covariance, General Properties of Distributions Binomial Distribution, Poisson Distribution, Gaussian Distribution, Chi-Square (χ^2) Distribution, Gamma Distribution, Commonly used distributions, Conditional probability, Bayes theorem, The likelihood function.

(25 % Weightage)

Unit-2

Inference : Review: Random Errors, Error Propagation, Systematic Errors, Basic Estimators, Maximum Likelihood, Inference: Bayesian inference, Error propagation with Bayiesian inference, Choice of the prior, Frequentist inference, Maximum likelihood estimates, Estimate of Gaussian parameters, Estimator properties, Neymans confidence intervals, Binomial intervals, Approximate error evaluation for maximum likelihood estimates, Two-dimensional uncertainty contours, Likelihood function for binned samples, Combination of measurements, Hypothesis tests

(25 % Weightage)

Unit-3

Essential Statistics for Data Analysis : Measures of Centrality, Measure of Dispersion, LEAST SQUARES, Fitting Binned Data, Linear Least Squares and Matrices, Chi-Square (χ^2) Test, Students t Test, Simple Linear Regression, Nonlinear Regression, Correlation, Time Series Analysis, Frequency Domain Analysis, Counting Statistics.

(25 % Weightage)

Unit-4

Hypothesis tests and Discoveries Level : The Neyman Pearson lemma, Projective likelihood ratio, Fisher discriminant, Artificial Neural Net-work, Boosted Decision Trees, Overtraining, Upper limits and Discoveries level: Poisson upper limit, Feldman Cousins intervals, Upper limits for event counting experiments, The modified frequentist approach, Treatment of nuisance parameters, Profile likelihood, Variations on test statistics, Random Number generator, Review of Monte Carlo technique.

(25 % Weightage)

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Probability theory: Classical probability, Frequentist probability, Subjective (Bayesian) probability,
5-8	Komogorov axiomatic approach, Probability distributions, PDFs in more dimensions, Mean, variance and covariance,
9-12	General Properties of Distributions Binomial Distribution, Poisson Distribution, Gaussian Distribution, Chi-Square (χ^2) Distribution,
13-16	Gamma Distribution, Commonly used distributions, Conditional probability, Bayes theorem, The likelihood function
17-20	Inference : Review: Random Errors, Error Propagation, Systematic Errors, Basic Estimators, Maximum Likelihood,

21-24	Inference: Bayesian inference, Error propagation with Bayiesian inference, Choice of the prior,
25-28	Frequentist inference, Maximum likelihood estimates, Estimate of Gaussian parameters, Estimator properties,
28-32	Neymans confidence intervals, Binomial intervals, Approximate error evaluation for maximum likelihood estimates,
32-36	Two-dimensional uncertainty contours, Likelihood function for binned samples, Combination of measurements, Hypothesis tests
36-40	Essential Statistics for Data Analysis : Measures of Centrality, Measure of Dispersion, LEAST SQUARES, Fitting Binned Data, Linear Least Squares and Matrices, Chi-Square (χ^2) Test,
41-44	Students-t Test, Simple Linear Regression, Nonlinear Regression, Correlation, Time Series Analysis, Frequency Domain Analysis, Counting Statistics.
45-48	Hypothesis tests and Discoveries Level : The Neyman Pearson lemma, Projective likelihood ratio, Fisher discriminant, Artificial Neural Network
49-52	Boosted Decision Trees, Overtraining, Upper limits and Discoveries level: Poisson upper limit, Feldman Cousins intervals, Upper limits for event counting experiments, The modified frequentist approach,
53-56	Treatment of nuisance parameters, Profile likelihood, Variations on test statistics,
57-60	Random Number generator, Review of Monte Carlo technique.

Essential Readings:

1. Statistics for Nuclear and Particle Physicists, Louis Lyons, Cambridge University Press (2018)
2. Statistical Methods in Experimental Physics, Frederick Jame, World Scientific Publishing Co. Pre. Ltd (2nd Edition).

Additional/Advance/Further Readings:

1. Data Analysis in High Energy Physics: A Practical Guide to Statistical Methods, edited by Olaf Behnke, Kevin Kröninger, Grégory Schott, Thomas Schörner-Sadenius, Wiley & sons
2. Statistical Methods for Data Analysis in Particle Physics, Luca Lista, Springer.