# COURSE STRUCTURE OF M.Sc. (PHYSICS) UNDER GIRIJANANADA CHOWDHURY UNIVERSITY

**A) Credit distribution for various courses in all four semesters:**

| Semester | Core Courses | | | Department Specific Elective(DSE) | | | Open Elective (OE) | | | Internship | Project | SEC | Total Credits |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Courses | Credits (L+T+P) | Total Credits | No. of Courses | Credits (L+T+P) | Total Credits | No. of Courses | Credits (L+T+P) | Total Credits | Total Credit | Credits | Total Credits | |
| I | 4 | 9+3+12 | 18 | 0 | 0 | 0 | 1 | 3+0+0 | 3 | 0 | 0 | 0 | 21 |
| II | 5 | 12+4+12 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 |
| III | 2 | 3+1+8 | 8 | 2 | 6+2+0 | 8 | 0 | 0 | 0 | 3 | 0 | 3 | 22 |
| IV | 2 | 6+2+0 | 8 | 2 | 6+2+0 | 8 | 0 | 0 | 0 | 0 | 8 | 0 | 24 |
| | Total Credits for Core Courses | | | | | | | | | | | | 56 |
| | Total Credits for Department Specific Elective Courses | | | | | | | | | | | | 16 |
| | Total Credits for Department Open Elective Courses | | | | | | | | | | | | 3 |
| | Total Credits for Internship | | | | | | | | | | | | 3 |
| | Total Credits for Project Courses | | | | | | | | | | | | 8 |
| | Total Credits for Skill Enhancement Courses | | | | | | | | | | | | 3 |
| | **Grand Total Credits** | | | | | | | | | | | | **89** |

### B) Course Structure in Semester I

| **Semester I** | | | | |
|---|---|---|---|---|
| **Total number of Core Course:5 (No Elective Course is offered in this Semester) MPY** | **Credits in Core Courses** | | | |
| | **Lecture (L)** | **Tutorial (T)** | **Practical(P)** | **Total Credits** |
| Mathematical Physics | 3 | 1 | 0 | 4 |
| Classical Mechanics | 3 | 1 | 0 | 4 |
| Quantum Mechanics | 3 | 1 | 0 | 4 |
| OEC | 3 | 0 | 0 | 3 |
| General Lab | 0 | 0 | 12 | 6 |
| Total Credits in Semester I | | | | 21 |

### C) Course Structure in Semester II

| **Semester II** | | | | |
|---|---|---|---|---|
| **Total number of Core Course:5 (No Elective Course is offered in this Semester)** | **Credits in Core Courses** | | | |
| | **Lecture(L)** | **Tutorial(T)** | **Practical(P)** | **Total Credits** |
| Atomic and Molecular Physics | 3 | 1 | 0 | 4 |
| Condensed Matter Physics | 3 | 1 | 0 | 4 |
| Statistical Mechanics | 3 | 1 | 0 | 4 |
| Nanomaterials | 3 | 1 | 0 | 4 |
| General Lab II | 0 | 0 | 12 | 6 |
| Total Credits in Semester II | | | | 22 |

**D) Course Structure in Semester III**

| **Semester III** | | | | |
|---|---|---|---|---|
| **Total number of Core Course :2**<br>**Total number of DSE Course :2**<br>**Internship: 1**<br>**SEC: 1** | **Credits in Core/Elective Courses** | | | |
| | **Lecture (L)** | **Tutorial (T)** | **Practical (P)** | **Total Credits** |
| Electronics | 3 | 1 | 0 | 4 |
| SEC | 3 | 0 | 0 | 3 |
| Gen Lab III | 0 | 0 | 8 | 4 |
| DSE1 | 3 | 1 | 0 | 4 |
| DSE2 | 3 | 1 | 0 | 4 |
| Internship | | | | 3 |
| Total Credits in Semester III | | | | 22 |

**E) Course Structure in Semester IV**

| **Semester IV** | | | | |
|---|---|---|---|---|
| **Total number of DSE Course :2**<br><br>**No. of Projects:1** | **Credits in DSE/OE/Project Courses** | | | |
| | **Lecture (L)** | **Tutorial (T)** | **Practical (P)** | **Total Credits** |
| Electromagnetic Theory and Electrodynamics | 3 | 1 | 0 | 4 |
| Nuclear and Particle Physics | 3 | 1 | 0 | 4 |
| DSE3 | 3 | 1 | 0 | 4 |
| Project | 0 | 0 | 16 | 8 |
| DSE4 | 3 | 1 | 0 | 4 |
| Total Credits in Semester IV | | | | 24 |

**F) Department Specific Elective (DSE) Courses to be offered:**

**Semester III (DSE1)**

Any two of the following courses are to be selected (If 1 is opted for DSE 1, then 1 has to be again opted for DSE 2, similarly for other course)

1. Course Name: Material Synthesis &Characterizations
2. Course Name: Advance Electronics

**Semester III (DSE2)**

1. Course Name: Thin Films Phenomena.
2. Course Name: Network Analysis & Microwave Electronics.

**Semester IV (DSE3)**

Any two of the following courses are to be selected (If 1 is opted for DSE 1, then 1 has to be again opted for DSE 2, similarly for the other course)

1. Course Name Laser & Spectroscopy
2. Course Name General Theory of Relativity & Cosmology

**Semester IV (DSE4)**

1. Course Name Nonlinear Optics
2. Course Name High Energy Physics

**Open Elective (OE) Courses to be offered**

1. Data Science and Machine Learning

## DETAILED SYLLABI:

## SEMESTER-I

| DSC | MATHEMATICAL PHYSICS | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 4 |

**Pre-requisite:** Graduation level Mathematics and Physics

**Course Objectives:**

1. To provide fundamental knowledge of complex variables.
2. To enable students to learn different properties of Fourier and Laplace Transforms.
3. To make students familiar with elementary probability theory and the fundamentals of group theory.
4. To provide knowledge about tensors and their applications.
5. To provide knowledge about special functions used in Physics.

**Course Outcome:**

After successful completion of the course, the students will be able to
CO1: Understand the fundamentals of complex variables, Fourier and Laplace transforms, Probability theory, Group theory and special functions
CO 2: Apply the knowledge of complex variables, probability theory, Fourier and Laplace transform to solve simple problems.
CO 3: Understand the properties of Tensors and apply them in different areas of Physics.
CO 4: remember the properties of special functions.

| Module 1: COMPLEX VARIABLES | 15 Hours |
|---|---|
| Fine Structure of One-Electron Atoms – Mass Correction, Spin-Orbit and Darwin Terms, Effect of Electric and Magnetic Fields: Zeeman, Paschen-Bach and Stark Effects, Ground State of Two-Electron Atoms – Perturbation Theory and Variational Methods, LS and JJ Coupling, Lande Interval and Selection Rules, Collision and Doppler Broadening. | |
| **Module 2: FOURIER AND LAPLACE TRANSFORMS** | **8 hours** |
| Fourier Transform, Convolution Theorem, Laplace Transforms, Laplace Transforms of derivatives, Substitution properties of Laplace Transform, Properties of gamma and beta functions, Error function and Dirac Delta functions. | |
| **Module 3: PROBABILITY AND GROUP THEORY** | **11 hours** |
| Elementary Probability Theory, Random Variables, Binomial, Poisson and Normal Distributions, Central Limit Theorem, Central difference formula, Iterative process, Newton-Raphson formula, Introductory Group Theory | |
| **Module 4: TENSORS** | **15 hours** |
| Contravariant and Covariant Tensor, Jacobian, Relative Tensor, Pseudo Tensors (Example: charge density, angular momentum), Riemann space (Example: Euclidean space and 4D Minkowski space), Christoffel Symbols, Transformation of Christoffel symbols, Covariant differentiation, Ricci's theorem, Divergence, Curl and Laplacian tensor form, stress and strain tensor, Hooke's Law in tensor form | |
| **Module 5: SPECIAL FUNCTONS** | **11 hours** |
| Series solution of differential equations with variable coefficients, Legendre, Hermite, Laguerre, Associated Laguerre polynomials, Bessel functions and their generating functions, Recurrence relations, Orthogonal Properties and Rodrigue's formula | |

**Textbook (s)**


1. Mathematical Methods for Physicists, G.B. Arkfen, H.J. Weber, F.E, Harris, 2013, 7th edition, Elsevier
2. Complex Variable (Schaum's Outlines), Murray Spiegel, Seymour Lipschutz, John Schiller, Dennis Spellman, Revised 2nd edition, McGraw Hill Education


**Reference Books**


1. Advanced Engineering Mathematics, E. Kreyszig (2nd edition, Pearson, 2002)
2. Mathematical Physics, B.D. Gupta, Vikas Publication House, 1986
3. Mathematical Physics, A.K. Ghatak, I.C. Goyal, S.J.Chua, Laxmi Publications Private Limited, 2016
4. Mathematical Methods, M.C. Potter and J. Goldberg, Prentice-Hall (2nd edition, 1987)

| DSC | CLASSICAL MECHANICS | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 4 |

**Pre-requisite:** Classical Mechanics of BSc Physics

**Course Objective**

(1) aims to understand the concepts of generalized coordinates and its subsequent applications to Lagrangian and Hamiltonian dynamics.
(2) to be familiar with Hamiltonian dynamics and its applications to solve complex problems in a simplified manner.
(3) enhance the knowledge regarding motion of the bodies under central force.
(4) to have a broader perspective of rigid body kinematics in terms of mathematical analysis.
(5) to enhance the knowledge of canonical transformation theory.

**Course Outcome:**

After successful completion of the course, the students will be able
CO1: to understand the concepts of generalized coordinates, Hamiltonian dynamics, central force, rigid body dynamics and canonical transformation theory. and its subsequent applications to Lagrangian and Hamiltonian dynamics.
CO 2: to apply the concepts of lagrangian and Hamiltonian dynamics to solve complex problems.
CO 3: to distinguish between different theories which explains the dynamics of systems.
CO 4: to evaluate various parameters involved in the classical dynamics theory in various problems.

| **Module 1: Lagrangian Dynamics** | **10 hours** |
|---|---|

Langrangian Dynamics: Constraints, Generalized coordinates, Concept of virtual work, D'Alembert principle, Langrange equation from D'Alembert principle, Velocity dependent potential, Expression for kinetic energy of a system in terms of Generalized coordinates, Cyclic coordinates, Symmetry properties and conservation theorems.

| **Module 2: Hamiltonian Dynamics** | **12 hours** |
|---|---|

Hamiltonian dynamics: Hamiltonian function H and conservation of energy: Jacobi's integral and its significance, Hamilton's equation, Routhian, Hamiltonian, Variation principle, Derivation of Langrange equation, Extension of Hamilton's Principle, to non-holonomic system, A hoop rolling without slipping on an inclined plane, Modified Hamilton's Variation principle, Derivation of Hamilton's equation from variation principle, Δ- variations, Principle of least actions in various forms, Introduction to Nonlinear Dynamical Theory and Chaos.

| **Module 3: Motion under Central Force** | **14 hours** |
|---|---|

The Two Body Central Force Problem: Central force and motion in a plane, Reduction of a two body central force to equivalent one body problem, Equation of motion and first integral, Differential equation for an orbit, Equivalent one dimensional problem and classification of orbits for some specific potential, Integral power law potential, Virial theorem, Relation between kinetic and potential energy, Kepler's Problems: Equation of orbit and the kind of the orbit, Motion in time.

| **Module 4: Rigid body kinematics** | **12 hours** |
|---|---|

The kinematics of rigid body motion: Independent co-ordinate of a rigid body, Orthogonal transformation, Formal properties of transformation matrix, Euler angles, Euler's theorem, Finite rotation, Infinitesimal rotations (contact transformation),Angular momentum, Moment of inertia tensor, Product of inertia, Inertia tensor, Principal moment ofinertia: Principal axis, Kinetic energy of motion of a rigid body about a point, Normal modes.

| **Module 5: Canonical transformation theory** | **12 hours** |
|---|---|

Canonical transformation and Hamilton Jacobi theory: Canonical transformation, Legendre transformation, Generating functions, Conditions for canonical transformation, Bilinear invariant Condition, Poisson's brackets, Langrange brackets, Invariance of Poisson bracket under canonical transformation, Angular momentum Poisson bracket relation, Hamilton Jacobi equation for Hamilton's principal function, Harmonic oscillator problem by Hamilton, Jacobi method, Hamilton's characteristic function.

| **Total Lecture hours** | **60 hours** |
|---|---|

**Textbook(s)**

| | |
|---|---|
| 1. | H. Goldstein: Classical Mechanics, Narosa Publishing House, 2001 |

| | |
|---|---|
| 2. | Jonh R Taylor, Classical Mechanics, University Science Books, U.S, 2004 |
| 3. | David Morin, Introduction to Classical Mechanics, Cambridge University Press, 2009 |
| 4. | Murray Spiegel: Theoretical Mechanics, McGraw Hill Education, 2017. |
| 5. | Frederick W. Byron and Robert W. Fuller: Mathematics of classical and Quantum Physics, Dover Publications; Revised ed. Edition,1992. |
| 6. | Steven H. Strogatz: Nonlinear Dynamics and Chaos: With Applications in Physics, Biology, Chemistry, and Engineering, CRC Press, 2015. |
| **Reference Books** | |
| 1. | N. C. Rana and P. S. Joag: *Classical Mechanics*, Tata Mc-Graw Hill, New Delhi, 1991. |
| 2. | S. L. Gupta, V. Kumar, H. V. Sharma: *Classical Mechanics*, Pragati Prakashan, Meerut, 2009. |
| 3. | P. V. Panat: *Classical Mechanics*, Narosa Publishing House, 2000. |

| **DSC** | **QUANTUM MECHANICS** | **L** | **T** | **P** | **C** |
|---|---|---|---|---|---|
| | | **3** | **1** | **0** | **4** |

| | |
|---|---|
| **Pre-requisite:** Graduation Level Physics and Mathematics | |
| **Course Objectives:** | |
| To provide knowledge of the formalism of Quantum Mechanics<br>To enable students to learn different aspects of Quantum Dynamics.<br>To make students familiar with angular momentum algebra<br>To provide knowledge about approximation methods in Quantum Mechanics.<br>To provide knowledge about Scattering and Relativistic Quantum Mechanics. | |
| **Course Outcome:** | |
| After successful completion of the course, the students will be able to<br>CO1: Understand the basic formalism of Quantum Mechanics, Qusantum Dynamics, Angular Momentum, Angular Momentum, Approximation Methods, Scattering and Relativistic Quantum Mechanics.<br>CO 2: Apply the knowledge of Quantum Mechanics to solve simple problems.<br>CO 3: Understand different aspects of angular momentum algebra for applications.<br>CO 4: Evaluate Quantum Mechanical problems using approximation methods. | |
| **Module 1:GENERAL FORMALISM OF QUANTUM MECHANICS** | **15 hours** |
| Mathematical properties of linear vector spaces, Dirac's Bra and Ket notation, Inner product, norm of a vector, orthonormality and linear independence, Basis and dimension, Outer product, projection operator, completeness, closure property, Hermitian operators, eigenvalues and eigenvectors, postulates of Quantum Mechanics, wave function, probability density, orthogonality criterion, Representation Theory, change of basis, Unitary operator, matrix representation of operators, position and momentum representations, Expectation values, uncertainty relation, Ehrenfest Theorem, Schrodinger time independent and time dependent formulation. | |
| **Module 2: QUANTUM DYNAMICS** | **12 hours** |
| Gaussian Wave Packet, Schrodinger picture, Heisenberg picture, solution of simple harmonic oscillator problem by the operator method, symmetry and conservation laws, symmetries in Quantum Mechanics – hydrogen atom and spherical harmonics, spatial translation, time translation, parity, time reversal, Density matrices | |
| **Module 3: ANGULAR MOMENTUM** | **10 hours** |
| Orbital Angular Momentum, angular momentum algebra, spin, Ladder operators and their matrix representations, spin angular momenta and Pauli matrices, symmetric and anti-symmetric wavefunctions, Pauli's Exclusion Principle, spin and statistics, addition of angular momenta, Clebsch-Gordan coefficients | |
| **Module 4: APPROXIMATION METHODS** | **10 hours** |
| Time Independent Perturbation Theory, Variational Theory, WKB Method and their applications, Time dependent Perturbation Theory, transition to a continuum of final states – Fermi's Golden Rule, applications to constant and harmonic perturbations, sudden and adiabatic approximations. | |
| **Module 5: SCATTERING AND RELATIVISTIVIC QUANTUM MECHANICS** | **13 hours** |
| Scattering: The scattering experiments, relationship of cross-section and wave function, scattering | |

| | |
|---|---|
| amplitude, phase shifts, partial wave analysis, Born Approximation and applications.<br>Relativistic Quantum Mechanics: Klien-Gordon and Dirac equations, Semi-classical theory of radiation – Einstein coefficients, atom field interaction, dipole matrix elements, spontaneous and stimulated emission rates, Selection Rules. | |
| **Total Lecture hours** | **60 hours** |

**Text Book(s)**

| | |
|---|---|
| 1.<br>2. | Quantum Mechanics : Theory and Application, A. Ghatak and S. Loknathan, 4th edition, Macmillan, 1999<br>Modern Quantum Mechanics, J.J. Sakurai (Addison-Wesley, 1993) |

**Reference Books**

| | |
|---|---|
| 1.<br>2.<br>3. | Quantum Mechanics, L. I. Schift, 3rd edition, Mc-Graw Hill, 1968<br>Introduction to Quantum Mechanics, D. J. Griffith, 2nd Edition, Pearson Education, 2005<br>Quantum Physics, S. Gasiorowicz, Wiley (3rd edition, 2003) |

| OEC | DATA SCIENCE AND MACHINE LEARNING | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

**Pre-requisite:** Calculus, Statistics and Linear Algebra

**Course Objectives:**

1. To impart to the students a comprehensive course on the basics and applications of Data Science and Machine Learning.
2. To disseminate lectures on classification and regression models and also to teach the challenges of deploying these models in real-world datasets.
3. To evaluate the working principles between Neural Networks and its implication in both classification and regression models.

**Course Outcome:**

At the end of a course, a student is able to:
CO 1: to understand the basics of statistics and apply the tools in data science.
CO 2: to apply machine learning models appropriately in any dataset, with the additional knowledge and skill of handling missing data, dimensionality reduction and undersampling/oversampling.
CO 3: to analyze the appropriate Neural Networks in diverse areas such as Image Recognition, Pattern Recognition, Classification, Trend Analysis, Time-Series anomaly detection and Prediction and so on.
CO 4: to evaluate the suitable machine learning algorithm taking into consideration the features of the given dataset.

| **Module 1: Basics of Statistics and Machine Learning** | **5 Hours** |
|---|---|

Statistical Distributions – Binomial, Poisson and Gaussian Distribution, Moments – Mean, Variance, Skew and Kurtosis, Central Limit Theorem, Covariance and Correlation, Bayes' Theorem.

| **Module 2: Regression and Classification Models** | **25 hours** |
|---|---|

Linear and Polynomial Regression, Logistic Regression, Support Vector Machine, K-Nearest Neighbors, Decision Tree and Naïve Bayes, K-Means Clustering, Recommendation Systems – Cosine Similarity, Reinforcement Learning.
Entropy, Overfitting and Underfitting, Confusion Matrix in Classification Models – Accuracy, Precision, Sensitivity, Recall and F1 Score.
Challenges of Real-World Datasets - Bias-Variance Trade-Off, Detection of Outliers, Feature Engineering and the Curse of Dimensionality, Dimensionality Reduction – Principal Component Analysis (PCA), Imputation Techniques for Missing Data, Undersampling and Oversampling in Unbalanced Datasets.
**Activity**-Mammogram, PIMA (Indian Diabetes) and Spam/Ham Detection.

| **Module 3: Deep Learning and Neural Networks** | **15 hours** |
|---|---|

Prerequisites of Deep Learning, Basics of TensorFlow and Keras, Recurrent Neural Network (RNN), Convolutional Neural Network (CNN), LSTM (Long Short-Term Memory), Time Series Prediction and Image Classification, Tuning Neural Networks: Training Rate and Batch Size Hyperparameters, Regularization with Dropout and Early Stopping.
**Activity**-Prediction of Political Affiliation, Image Recognition and Chaotic Time-Series Prediction.

**Textbook (s)**

| | |
|---|---|
| 1. | Practical Statistics for Data Scientists: 50+ Essential Concepts Using R and Python, 2nd Edition, P. Bruce, A. Bruce and P. Gedeck (2020). |

| | |
|---|---|
| 2.<br>3. | Hands-On Machine Learning with Scikit-Learn, Keras and TensorFlow, 2nd Edition, A. Green (2019).<br>Data Science From Scratch: First Principles with Python (O'Reilly), 2nd Edition, J. Grus (2019). |
| **Reference Books** | |
| 1.<br>2. | The Art of Statistics: Learning from Data (Pelican Books), David Spiegelhalter (2020).<br>Introducing Data Science: Big Data, Machine Learning, and More, Using Python Tools (Dreamtech Press), D. Cielen, A.D.B. Meysman and M. Ali (2016) |

| DSC | PHYSICS LABORATORY - I | L | T | P | C |
|---|---|---|---|---|---|
| | | 0 | 0 | 12 | 6 |

**Pre-requisite:** Basic Computer Skills.

**Course Objectives:**

**Course Objective** :

1) To gain a broad perspective about the uses of computers in engineering industry. .
2) To develop basic understanding of computers, the concept of algorithm and algorithmic thinking.
3) To improve the ability to incorporate exception handling in object-oriented programs.
4) To develop the use of the C programming language to implement various algorithms and develops the basic concepts and terminology of programming in general.

**Course Outcome:**

After successful completion of the course, the students will be able

CO1: To learn the basic knowledge in fundamentals of programming, algorithms and programming technologies and fundamentals of Computer Science.
CO2: To understand the basic idea of how to control the sequence of a program and give logical output.
CO3: To Develop C programs to solve simple engineering problems using looping constructs.
CO4: To apply the concept of Strings for writing programs related to character array.

**List of Experiments:**

1) Introduction to Programming, constants, variables and data types, operators and Expressions, I/O statements, scanf and printf, c input and c output

a) Write a program to display a string of alphabets ex: Hello World.
b) Write a program to take two values using standard input function and find:
   i) Addition of two values.
   ii) Subtraction of a value from another value.
   iii) Multiplication of two values.
   iv) Division between two values.
   v) Modulo division between two values.
c) Write a program to read a character in upper case and then print in lower case
d) Write a program to convert degrees Fahrenheit into degrees Celsius.
e) Write a program to calculate the bill amount for an item given its quantity sold, value, discount and tax display the result using standard output function.

2) Programs using simple control statements such as if-else, while, do-while, for loop etc.

a) Write a program to find whether the given number is even or odd.
b) Write a program to find whether a given year is a leap year or not.
c) Write a program to calculate the root of a quadratic equation.
d) Write a program to display the sin(x) value where x ranges from 0 to 360 in steps of 15.
e) Write a program to determine whether an entered character is a vowel or not by using switch case statement.
f) Write a program to calculate the average of numbers entered by the user using while statement.

g) Write a program using do-while loop to display the square and cube of first n natural numbers.
h) Write a program to calculate $X^n$ by using for loop.
i) Write a program to calculate sum of squares of first *n* even numbers.
j) Write a program that accepts any number and prints the number of digits in that number.
k) Write a program to enter hexadecimal number and display the decimal equivalent of this number.
l) Write a program to calculate square root of a number by using break and continue statement.

3) Programs using Arrays: declaring and initializing arrays. Program to do simple operations with arrays Strings – inputting and outputting strings. Using string functions such as strcat, strlen etc.

a) Write a program to read and display *n* numbers using an array.
b) Write a program to arrange the elements of an array in ascending order.
c) Write a program to interchange the largest and the smallest number in the array.
d) Write a program to program to delete number from an array that is already sorted in ascending order.
e) Write a program to merge two unsorted arrays Write a program to implement linear search.
f) Write a program to print the elements of a 2D array.
g) Write a program to read and print the elements of a matrix.
h) Write a program to find the sum of two same order matrices and print the sum matrix.
i) To find the product of two matrices and print the product matrix.

4) Use of strings :
a) Write a program to input and display a string.
b) Write a program to concatenate two strings taken as input using standard input functionand display.
c) Write a program to find if a string is palindrome or not.
d) Write a program to reverse a string.

5) Write a program (by using function) :
a) Sum of two numbers.
b) Subtraction of a value from another value.
c) Multiplication of two values.
d) Division between two values.

6) Solve the s-wave Schrodinger equation for the ground state and the first excited state of the Hydrogen atom:

$$\frac{d^2Z}{dr^2} = A(r)u(r), A(r) = \frac{2m}{h^2}[V(r) - E], \text{ where } V(r) = -\frac{e^2}{r}$$

Here, m is the reduced mass of the electron. Obtain the energy Eigenvalues and plot the corresponding wave functions. Remember that the ground state energy of the hydrogen atom is -13.6 eV Take e = 3.795 $(eVÅ)^{1/2}$, ħc =1973 (eVÅ) and m = 0.511x10eV

**Textbook (s)**

1. PROGRAMMING IN ANSI C BY E. BALGURUSWAMY, TATA MC-GRAW HILL.
2. PROGRAMMING WITH C, SCHAUM SERIES.
3. A FIRST COURSE IN PROGRAMMING WITH C, T. JEYAPOOVAN, VIKASH PUBLISHING HOUSE PVT. LTD.
4. COMPUTER FUNDAMENTALS AND PROGRAMMING IN C, REEMA TAHREJA, OXFORD HIGHER EDUCATION

## SEMESTER - II

| | | L | T | P | C |
|---|---|---|---|---|---|
| DSC | **ATOMIC AND MOLECULAR PHYSICS** | **3** | **1** | **0** | **4** |

**Pre-requisite:** Quantum Mechanics.

**Course Objectives:**

1. To impart a comprehensive course on the applications of Quantum Mechanics in the Physics of Atoms and Molecules.
2. To disseminate lectures on the Molecular Physics of Diatomic Molecules.
3. To evaluate the connection behind spectroscopic methods such Raman Effect, Electron Spin Resonance (ESR) and Nuclear Magnetic Resonance (NMR) and Molecular Physics.
4. To teach students the physics behind the operation of Lasers and the properties associated with it.

**Course Outcome:**

After successful completion of the course, the students will be able

CO 1: to understand the application of Perturbation Theory in the Fine Structure of Hydrogen and spectroscopic methods such as Zeeman and Stark Effect.

CO 2: to interpret the physics behind the Rotational, Vibrational and Electronic structure of Diatomic Molecules.

CO 3: to analyze the physics of various spectroscopic methods such as Raman Effect, ESR and NMR based on the lectures of Molecular Physics.

CO 4: to comprehend the operating principles of Laser, the properties and the numerous types of Lasers.

| **Module 1: Atomic Physics** | **20 Hours** |
|---|---|

Fine Structure of One-Electron Atoms – Mass Correction, Spin-Orbit and Darwin Terms, Effect of Electric and Magnetic Fields: Zeeman, Paschen-Bach and Stark Effects, Ground State of Two-Electron Atoms – Perturbation Theory and Variational Methods, LS and JJ Coupling, Lande Interval and Selection Rules, Collision and Doppler Broadening.

| **Module 2: Molecular Physics - I** | **10 hours** |
|---|---|

Born-Oppenheimer approximation for diatomic molecules, Rotational, Vibration and Electronic Structure of Diatomic Molecules, Spectroscopic terms, Electronic Structure - Molecular Symmetry and the States, Molecular Orbital and Valence Bond Methods for Hydrogen molecule and ion.

| **Module 3: Molecular Physics - II** | **15 hours** |
|---|---|

Rotational Spectra of Diatomic Molecules, Isotope Effect, Vibrational Spectra of Diatomic Molecules - Harmonic and Anharmonic Vibrators, Vibration-Rotation Spectra, Electronic Spectra of Diatomic Molecules - Vibrational Structure of Electronic Transitions, Rotational Structure of Electronic Bands - P, Q, R branches, Fortrat diagram, Franck-Condon principle, Electron Spin and Hund's cases, Raman Effect, ESR and NMR.

| **Module 4: Lasers** | **15 hours** |
|---|---|

Operating Principle of Laser – Threshold Condition for Laser Oscillation, Rabi frequency, Laser Pumping, Population Inversion and Resonator Modes, Multilevel rate equations and saturation, Laser Properties and Profile of Spectral Lines, Types of Lasers - He-Ne, CO2 and Semiconductor.

**Textbook (s)**

1. **Physics of Atoms and Molecules ($2^{nd}$ edition Pearson, January 2003), B. H. Bransden and C. J. Joachain.**
2. **Molecular Structure and Spectroscopy (Prentice Hall India, January 2007), G. Aruldhas.**
3. **Optical Electronics (Cambridge India, January 2017), Ajoy Ghatak and K. Thyagarajan.**

**Reference Books**

1. **Principles of Quantum Mechanics (Cambridge University Press, August 2016), David J. Griffiths.**
2. **Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles ($2^{nd}$ Paperback Wiley, January 2006), R. Resnick and R. Eisberg.**
3. **Fundamentals of Molecular Spectroscopy (Tata McGraw Hill, June 2001), C. Banwell and E. McCash.**

| DSC | CONDENSED MATTER PHYSICS | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 4 |

**Pre-requisite:** BSc course on Condensed Matter Physics

**Course Objective**

(1) aims to enhance the concepts of crystalline nature of solids with a complete knowledge of vibrations in the crystal through proper mathematical analysis.
(2) to be familiar with different types of crystals in detailed manner understanding their electric nature.
(3) enhance the knowledge regarding ferromagnetic with the help of different theories.
(4) to have a broader perspective of superconductors and their properties via varied equations
(5) to enhance the knowledge of band theory of solids.

**Course Outcome:**

After successful completion of the course, the students will be able
CO1: to analyze the nature of crystalline solids by learning experiments with their result analysis and from concept of elastic waves.
CO 2: to apply the theory of ferroelectric transitions to understand the dynamics, thermodynamics and phase transition.
CO 3: to apply various theories to have a broader knowledge of ferromagnetic.
CO 4: to analyze the properties of superconductors with the results provided by various mathematical theories.
CO 5: to apply quantum mechanics to understand the band theory of solids in detail.

| **Module 1: Crystalline solids** | **15 hours** |
|---|---|

Fundamentals of crystal structure, Diffraction of waves by crystals, Reciprocal lattice and its application to diffraction Technique, Laue, Powder and rotating crystal method, Crystal structure factor and atomic form factor, Lattice Vibrations: Quantization of elastic waves, Phonon momentum and inelastic scattering by phonons.
Defects in Crystal: Point defects, Colour centres, F-centres, Line defects and planer defects, Role of dislocations in crystal growth

| **Module 2: Ferroelectrics** | **10 hours** |
|---|---|

Ferroelectrics: Classification of ferroelectric crystals, Theory of the ferroelectric displacive transitions: Polarization catastrophe, Soft optical phonon, Thermodynamics of ferroelectric transition, Ferroelectric domains, Antiferroelectric, Piezoelectric and pyroelectric material. Phase Transition: First and second order transition, Long range order, Short range order and Bragg William model.

| **Module 3: Ferromagnetism** | **10 hours** |
|---|---|

Weiss theory of ferromagnetism, Exchange interaction: Heisenberg model, Ferromagnetic domains, Origin of domains, Anisotropy energy, Bloch wall, Curie-Weiss law for susceptibility, Antiferromagnetic, Ferrimagnetic order, Spin wave and magnons.

| **Module 4: Superconductivity** | **10 hours** |
|---|---|

Basic phenomena, Meissner effect, Critical field, Type- I and Type- II superconductors, Heat capacity, Isotope effect, London equations, Coherence length, BCS theory of superconductivity, Flux quantization, Normal tunneling, dc and ac Josephson Effect, SQUID, High temperature superconductors.

| **Module 5: Band Theory of Solids** | **15 hours** |
|---|---|

Band Theory of Solids: Electrons in periodic lattice, Bloch theorem, Nearly free electron model, Tight binding approximation, Fermi surface, de Hass-Van Alphen effect, Cyclotron resonance, Magnetoresistance, Quantum Hall effect.
Optical Properties: Refractive index, Electronic polarization, Optical absorption, Photoconductivity, Relationship between absorption coefficient and band gap recombination.

| **Total Lecture hours** | **60 hours** |
|---|---|

**Text Book(s)**


| | |
|---|---|
| 1. | C. Kittel: *Introduction of Solid State Physics*, 7th edition, John Wiley & Sons, 2004. |
| 2 | A.J. Dekker: *Solid State Physics*, Prentice Hall, 1957. |
| 3 | N.W. Ashcroff N.D. Mermin: *Solid State Physics*, Holt, Rinehart and Winston, 1976. |
| 4 | J.M Ziman: *Principles of the theory of Solids*, Cambridge University Press, 2000. |
| 5 | Nicola Spaldin, *Magnetic Materials*, |

| Reference Books | |
|---|---|
| 1. | J.P. Shrivastava: *Elements of Solid State Physics, 2nd edition*, PHI, New Delhi, 2006. |
| 2. | L.V. Azaroff*: Introduction to Solids*, TMH edition, 1996. |
| 3. | M. Tinkham: *Introduction to superconductivity*, Dover Publications, 2004. |

| DSC | STATISTICAL MECHANICS | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 4 |

**Pre-requisite:** Graduation Level Physics

**Course Objectives:**

To provide fundamental knowledge about Statistical Mechanics for describing systems containing large number of particles.
To introduce the advance concepts of Classical Statistical Mechanics so that students will be equipped with sufficient knowledge of the subject.
To impart fundamental knowledge of Quantum Statistical Mechanics and its applications.
To develop the interest and ability among students to solve challenging physical problems by the application of techniques of Statistical Mechanics in future.

**Course Outcome:**

After successful completion of the course, it is expected that the students will
CO1: be equipped with sufficient knowledge of the Statistical Mechanics and hence will be able to look critically for analyzing any physical phenomena.
CO 2: Apply different aspects of Classical Statistical Mechanics.
CO 3: Understand and appreciate different features of Quantum Statistical Mechanics so as to gain insight into diverse physical phenomena.
CO 4: Appreciate the universality of critical exponents characterizing phase transitions.

| **Module 1: REVIEW OF THERMODYNAMICS AND TOPICS IN PROBABILITY THEORY** | **10 hours** |
|---|---|
| Statistical basis of thermodynamics, probability concepts, entropy of a probability distribution, random walk, microstate and macrostate, phase space, Liouville theorem | |
| **Module 2: CLASSICAL STATISTICAL MECHANICS** | **19 hours** |
| Concept of ensembles, microcanonical, canonical and grand canonical ensembles, system in grand canonical ensembles, Partition functions, principle of equipartition of energy.<br>Energy of Harmonic oscillator, partition function for canonical ensemble, energy fluctuations in the canonical ensemble, partition function and Thermodynamic function for grand canonical ensemble, density fluctuations in the grand canonical ensemble, theory of paramagnetism, negative temperature. | |
| **Module 3: QUANTUM STATISTICAL MECHANICS** | **15 hours** |
| Indistinguishable particles in quantum mechanics, Bosons and Fermions, Bose-Einstein statistics, ideal Bose gas, photons, Bose-Einstein condensation. Fermi-Dirac statistics, Fermi energy, ideal Fermi gas, Density operator, Quantum Liouville equation, pure and mixed states. | |
| **Module 4: FLUCTUATIONS AND PHASE TRANSITIONS** | **16 hours** |
| Brownian motion; diffusion equation, approach to equilibrium: the Fokker –Planck equation, introduction to non-equilibrium processes<br>First and second order phase transition, phase diagram, Interacting spin systems, the Ising model (one dimension), paramagnetic and ferromagnetic phases, liquid helium | |
| **Total Lecture hours** | **60 hours** |

**Text Book(s)**

1. *Statistical Mechanics*, R.K. Pathria (Butterworth-Heinemann, Second Edn, 1996).
2. *Statistical Mechanics*, K. Huang (2ndEdition, Wiley-India, 2008).
3. *Statistical Physics* : L. Landau and E.M. LifShitz

**Reference Books**

| | |
|---|---|
| 1 | *Statistical Mechanics: An Advanced course with problems and solutions*, Ryogo Kubo (North-Holland, 1965) |
| 2 | *Statistical Phys*ics : F. Reif |

| DSC | NANOMATERIALS | L | T | P | C |
|---|---|---|---|---|---|
| | | **3** | **1** | **0** | **4** |

**Pre-requisite:** Graduation Level Physics

**Course Objectives:**

To provide fundamental knowledge about nanomaterials
To enable students to learn different methods of fabrication and characterization of nano structured materials.
To make students familiar with specific features of nanoscale growth and thermodynamics.
To learn about the remarkable properties of nanomaterials.
To provide knowledge about application of nanomaterials.

**Course Outcome:**

After successful completion of the course, the students will be able to
CO1: Understand physics at the nanoscale.
CO 2: Understand different methods of synthesis and characterization of nanomaterials.
CO 4: Analyse the properties specific to nanomaterials.
CO 5: Apply properties of materials at the nanoscale in emerging areas.

| **Module 1: INTRODUCTION** | **10 hours** |
|---|---|

Nano size scale, History of Nanotechnology, Quantum Mechanics and Fluctuation in nanostructure systems, surface area to volume ratio, surface energy, chemical potential as a function of surface curvature, Electronic stabilization and steric stabilization, Idea of zero, one and two dimension structures, vacancies and dislocations in nanocrystals, Effect of nanoscale dimensions on various properties.

| **Module 2: SYNTHESIS AND CHARACTERIZATION** | **19 hours** |
|---|---|

Synthesis:
Top-down and bottom-up approaches, synthesis of metal, semiconductor, carbon and bio nanomaterials, Grains and grain boundaries, distribution of grain sizes, pores, strains. Thin film preparation methods by thermal evaporation, sputtering and pulsed laser deposition methods. Gas phase synthesis of nanopowders, chemical and colloidal methods, mechanical milling, dispersion in solid-doped glasses and sol gel method, functionalization of nanoparticles.
Characterization:
Characterization by diffraction method and optical methods. Chemical characterizations-Raman spectroscopy, XPS, XAS and EXAFS.

| **Module 3: STRUCTURE AND THERMODYNAMICS AT NANOSCALE** | **9 hours** |
|---|---|

Specific features of the nanoscale growth, control of size, nucleation, growth and aggregation. Crystalline phase transitions and geometric evolution of the lattice in nano crystals, thermodynamics of very small systems. Self-assembling nanostructured molecular materials and devices.

| **Module 4: PROPERTIES** | **11 hours** |
|---|---|

Melting point and lattice constants, Mechanical properties, Optical properties; Surface Plasmon effect, Quantum size effect, Electrical conductivity; Surface Scattering, Change of Electronic structure, Quantum Transport, Effect of microstructure, Ferroelectric and dielectrics, Superparamagnetism.

| **Module 5: APPLICATIONS** | **11 hours** |
|---|---|

Application in molecular and nano-electronics, Biological applications (imaging, drug delivery), Quantum well and quantum dot devices, Energy application of nanomaterials; Photochemical cell, Lithium –ion battery, Hydrogen storage and thermo-electrics, Environmental application, Photonic crystals.

| **Total Lecture hours** | **60 hours** |
|---|---|

**Text Book(s)**

| | |
|---|---|
| 1. | *Nanostructures and Nanomaterials: Synthesis, Properties and Applications* - Guozhong Cao and Ying Wang, *2nd Ed.*, World Scientific, Singapore, 2011. |
| 2. | *Introduction to Nanoscience* - S.M. Lindsay, Oxford University Press, New York, 2010. |
| 3. | *Introduction to Nanotechnology*, C. P. Poole Jr. & F. J. Owens (Wiley-Interscience, 2003) |

| DSC | General Lab-II | L | T | P | C |
|---|---|---|---|---|---|
| | | 0 | 0 | 12 | 6 |

**Prerequisite : Graduate level Laboratory knowledge**

**Course Objective** :

This course aims at performing basic physics experiments by the students. The students will be able to determine
1. some physical parameters and design circuits to understand important principles of Physics.
2. Enable the students to analyze problems starting from first principles, evaluate and validate experimental results, and draw logical conclusions thereof.
3. Make the students to understand that acquiring knowledge and skills appropriate to their professional activities is a never-ending process.
4. This lab will help the students to understand and Introducing basic concepts via diffraction methods, lattice vibrations and free electrons, Hall Effect.
5. Enhance the knowledge of students to the band structures for studying different materials.

**Course Outcome:**

**CO1**: Students will gain in-depth knowledge about the molecular structure using various concepts.
**CO2**: To understand the basic idea of different types of preparation methods of nanomaterial's and their characterization techniques and interpretations.
**CO3**: Students will be able to answer about various spectroscopic techniques and their modern developments.
**CO4**: To increase the level of understanding of students about the various spectra of atoms, molecules and the use of electromagnetic radiation in understanding the tiny particles and the whole universe.

**List of Experiments :**

1. To determine the first excitation potential of a Gas by Frank-Hertz experiment.
2. To find the wavelengths of the spectral lines of Hydrogen and hence determine the value of Rydberg constant.
3. Determination of e/m of an electron.(Zeeman effect ).
4. Measurement of Magneto resistance of the supplied material.
5. Observe diffraction of the beam of electrons on a graphitized carbon target and calculate the intra-atomic spacing's in the graphite.
6. Determination of solar cell characteristics.
7. Study of Dielectric constant and Curie temperature of a ferromagnetic sample.
8. Determination of planks constant by planks blackbody radiation experiment.
9. Determine the Band gap of a semiconductor by using four probe methods.
10. Perform the Hall Effect experiment by recording the Hall voltage at different sample currents under different magnetic field strengths. Plot suitable graph and hence determine Hall coefficients. Identify conductivity type of the semiconductor.
11. To study the dispersion relation for the monatomic and diatomic lattice.
12. Familiarization with ORIGIN Graphing and Analysis Software for analysis of absorption & photoluminescence spectra and X-ray diffraction patterns (Demo).
13. Preparation of e CdS nanostructures and record UV-Vis absorption spectra. Examine possible quantum confinement effect.

**Text Books :**

1) Advanced Practical Physics for students, B.L. Flint and H.T. Workshop, 1971, Asia Publishing House
2) Advanced level Physics Practical's, Michael Nelson and Jon M. Ogborn, 4thEdition, reprinted 1985, Heinemann Educational Publishers.
3) A Textbook of Practical Physics, I. Prakash & Ramakrishna, 11thEd., 2011, Kitab Mahal.

**Reference Books**

1. *Nanoscience and Nanotechnology* - B.K. Parthasarthy (Edited), Isha Books, Delhi, 2007.
2. *Nanostructured Materials and Nano Technology*, H. S. Nalwa (Ed.) (Academic Press, 2002)