BERHAMPUR UNIVERSITY

Syllabus

For

Two Years M.Sc. Program

2024-25

PG Department of Physics

Berhampur University,

Berhampur-76007 (Odisha)

2024

Course Curriculum & Syllabus-2024
POSTGRADUATE DEPARTMENT OF PHYSICS

BERHAMPUR UNIVERSITY, BHANJABIHAR, ODISHA, INDIA

1. About the Department:

The Department of Physics was started in 1969 with a Vision to spread Science and provide higher education. Dr S.N. Behera was the founder of this Department. The Department offers a two-year Master's degree Course in Physics, besides M.Phil. and PhD. Since its inception, the Department has grown appreciably with the leadership of Prof. P. K. Mishra, not only in terms of student and faculty strength but also in introducing new courses and broadening research activities. The postgraduate curricula have recently undergone significant orientation congruent with the development and trends in different thrust areas of subjects like condensed matter physics, materials science, photonics, nuclear Science, nuclear astrophysics, particle physics, cosmology, etc.

The Department contributed to research and published more than 400 papers on the above subjects in international and national journals. The hallmark of the Department is sincere teaching and outstanding research. Several candidates received their Ph. D.s from the Department. Faculty members of this Department, Prof. N.C Mohapatra, Prof G.S.Tripathi, and Prof. R . Sahu, received the "Samanta Chandra Sekhar Award" by Odisha Bigyan Academy for the Years 1996, 2005 and 2010, respectively.

The Department has established a centre for applied photonics with financial support from DST--FIST to conduct experimental research in photovoltaic and nanomaterials. The Department is also coordinating the Centre of Excellence for Nano Science and Technology for sensor development, a project of Rs three hundred lakhs sanctioned by OHEPEE, the Department of Higher Education, and the Government of Odisha.

The Department regularly organizes seminars, conferences, and summer school /winter school.

Many of its students went abroad for higher studies; some are absorbed in variousinstitutions there. Our students are also faculty members in leading national-level institutions and laboratories. This Department is a vibrant place for academics and research.

2. A. Faculty Members:

1. Sukanta K. Tripathy, Professor (Applied Photonics,Experment and Theory)
2. Sidhartha S. Panda, Professor (High Energy Physics,Theory)
3. Sashi S. Behera, Assistant Professor (Condensed Matter Physics, Theory)
4. Kusha K. Naik, Assistant Professor (Condensed matter Physics, Experiment)

B. Honorary Professors

1. Rankanidhi Sahu (Nuclear Physics,Theory)
2. Gouri S. Tripathi.(Condensed Matter Physics,Theory)

3. Facilities in the Department.

Experimental Research:

1. **Centre for Applied Photonics:** This centre was established with DST FIST funding for third generation solar cell research. This centre consists of 1. Nano Materials Synthesis Laboratory 2.Device Fabrication Laboratory 3. Device Characterization Laboratory. Coating facilities like Spin, dip, and vacuum coating are available in this centre. Absorption Spectrometer, Keithly Source meter, LCR Meter, Impedance analyzer, and Solar Simulator are also available for characterization. Anexperimental setup was designed in this centre to characterize optical fibre-based sensors.For more detail one can contact skt.phy@buodisha.edu.in

2. **Centre of Excellence**: The Department is also coordinating the Centre of Excellence in Nanoscience and Technology to develop Sensors.which is set up with the financial assistant from OHEPEE, under the Higher Education Department, Govt, of Odisha. The centre aims to create prototypes of low-cost sensors for healthcare, the environment and food security.A centre for nanophotonics and quantum enabled sensing is also established under this CoE,where currently heralded single photon source is utilised for sensing applications.For more detail one can contact skt.phy@buodisha.edu.in

3.Theoretical Research:

The Department also facilitates theoretical research in Condensed Matter Physics and High Energy Physics. For more detail one can contact

4. MoU and Collaboration

The Department has MoU with IoP, Bhubaneswar and collaborated with BARC Mumbai,IISER Berhampur for photonics research activities.

5. Syllabus:

M.SC. PHYSICS SYLLABUS

BERHAMPUR UNIVERSITY BHANJA BIHAR, BERHAMPUR-7600007

1	Course	Course title	Hrs per Week	Credit	Exam Hrs	Marks		Total
						Mid Sem	End sem	
I	PHY-C 101	Mathematical Methods in Physics	4	4	3	30	70	100
	PHY-C102	Classical Mechanics	4	4	3	30	70	100
	PHY- C103	Computer Programming And Numerical Analysis	4	4	3	30	70	100
	PHY-C104	Quantum Mechanics-I	4	4	3	30	70	100
	PHY-C105	Vedanta Philosophy in Modern Physics Perspective	4	4	3	30	70	100
	PHY- P106	Computer Programming In Physics(Practical)	12	6	6	30	70	100
		Total	**28**	**26**				**500**
II	PHY- C201	Classical Electrodynamics	4	4	3	30	70	100
	PHY- C202	Statistical Mechanics	4	4	3	30	70	100
	PHY- C203	Basic Solid-State Physics	4	4	3	30	70	100
	PHY- C204	Quantum Mechanics-II	4	4	3	30	70	100
	PHY-P205	Optics(Practical)	12	4	4	30	70	100
	PHY-CT-200	SWAYAM	04	Online Course				
	PHY-VAC206	Material Characterization Technique OR DFT and Materials Modelling						
		Total	**28**	**26**				**500**

Note: C: Core paper, P: Practical, E: Elective, S: Seminar, VAC: Value added course, CT:Credit transfer

A student has to register for 14 core papers (including three core labs), six elective papers (including one lab in elective), and one project and seminar, two value-addedcourses

III	PHY- C301	Relativistic Quantum Mechanics & Field Theory	4	4	3	30	70	100
	PHY- C302	Electronics	4	4	3	30	70	100
	PHY- E303 A OR PHY- E303B	Condensed Matter & Materials Physics-I Or Nuclear Science-1(NP.)	4 4	4 4	3 3	30 30	70 70	100 100
	PHY- EP304	Modern Physics(Practical)	12	6	4			100
	PHY-VAC305	Optical Fiber Sensor Or Fiber Optics Or Atomic And Molecular Spectra				30		
	PHY- CT300	Fibre Optics And Optoelectronics	04	04	03	30	70	100
		Total	**28**	**22**				500
IV	PHY- E401A **OR** PHY-E401B	Elementary Particle Physics Or GTR	4 4	4 4	3 3	30 30	70 70	100 100
	PHY- C402	Basic Nuclear Physics	4	4	3	30	70	100
	PHY-CE403	Project And Seminar	4	4			50 50	100
	PHY- CE404A **OR** PHY- CE404B	Condensed Matter &Materials Physics II Or Nuclear Science-II	4 12	4 6	3 4	30 30	70 70	100 100
	PHY- CE405A OR PHY- CE405B	Condensed Matter &Materials Physics(Practical) Or Nuclear Science (Practical)	12	6	4	30	70	100
	PHY- AC406	Cultural Heritage Of South Odisha.						
		Total	**28**	**22**				**500**
		Grand total	**120**	**96**				**2000**

Note: C: Core paper, P: Practical, E: Elective, S: Seminar, VAC: Value added course, CT: Credittransfer

A student has to register for 14 core papers (including three core labs), six elective papers (including one lab in elective), and one project and seminar, two value-added courses

Programme Outcome:

- Instil among the students an attitude of being inquisitive so that they are capable of independent and critical thinking.
- Train the students so they can objectively carry out scientific and/or otherwise investigations without being biased or having any preconceived notions.
- Equip the students with such skills to make them understand the mysteries of nature at different scales of space and time, from subnuclear to cosmological.
- Enable the students to analyze problems starting from first principles, evaluate and validate experimental results, and draw logical conclusions.
- Prepare the students to pursue research careers, academic careers, and industries in Physical Science and allied fields.
- Imbibe effective scientific and/or technical communication abilities among the students.

First Semester

Sub Code: PHY- C101	**Mathematical Methods in Physics**	
Semester:1	**Credit:4**	**Core Course**
Pre-requisites: Basic understanding of fundamental analysis, Complex numbers, Group theory		
Course outcome: ✓ To learn about various mathematical tools employed to study physics problems. ✓ To get good experience using and understanding areas like complex variables, Tensor analysis, Group Theory and special functions. ✓ To strengthen the students' analytical abilities and help them formulate different relationships in mechanics and physics compactly.		

Unit-1 **12 hours**

Complex Variables: Analytic functions, Contour integrals, Cauchy's integral theorem, Laurent's series, singular points, residues and the Residue Theorem, Evaluation of real definite and indefinite integrals by contour integration, Indented semi-circular contour, evaluation of single and multi-valued functions, branch points and branch cuts, Contour integration involving branch point.

Unit -2 **12 hours**

Tensors: Introduction, Types of tensor, Invariant tensor, epsilon tensor, Pseudo tensor, thealgebra of tensor, Quotient law, Metric Tensor, Covariant derivative of tensor, Fundamental Tensor, Cartesian tensor, Christoffel symbol.

Unit -3 **12 hours**

Group Theory: Definitions of groups, subgroups and classes, Isomorphism, Homomorphism, Cayley's theorem, Group representations, Orthogonality theorem, characters, Orthogonality relation for group character, Character table, Preliminary idea about infinite group, Calculation of generator, Calculation of generator associated with SU (2) and SO(3) group,

Unit -4 **12 hours**

Special Functions: Legendre Polynomials, generating functions, Recurrence formulae, Orthogonality properties of Legendre's polynomial of 1st kind, Bessel generating function, Bessel function of 1st and 2nd Kind, Recurrence formulae, Orthogonality properties of Bessel's polynomials, Spherical Bessel functions, Fourier and Laplace transformation.

Textbooks:

1. Mathematical Methods of Physics by Mathews and Walker (W. A. Benjamin Inc.)
2. Matrices and Tensors in Physics by A. W. Joshi (New Age International Publisher)
3. Mathematical Methods in the Physical Science by Mary L. Boas (Wiley- India)

Reference Books:

1. Mathematical Methods for Physicist by G. Arfken and H. Weber, Academic Press (Elsevier)
2. Elements of Group Theory by A. W. Joshi (New Age International Publisher)
3. Mathematical Physics by H. K. Das and Dr R. Verma (S. Chand & Company LTD.)
4. Mathematical Physics by P. K. Chattopadhyaya (New Age International)

Sub. Code: PHY- C102		**Classical Mechanics**
Semester: 1	**Credit: 4**	**Core Course**
Pre-requisites: Basic understanding of generalized coordinate, Newtonian dynamics		
Course outcomes: ✓ To understand degrees of freedom and dynamics of a rigid body motion. ✓ To understand complex kinds of gyroscopic Motion as a heavy symmetric top. ✓ To make a clear distinction between Lagrangian and Hamiltonian dynamics. ✓ To understand Hamiltonian dynamics and the evolution of quantum mechanics. ✓ To understand small oscillation occurring in micro and macro-systems		

Unit-1 **10 hours**

KINEMATICS OF RIGID BODY MOTION:
Independent coordinates of a rigid body, Orthogonal transformations, Eulerian angles, infinitesimal rotations, rate of change of vector, Coriolis force, angular momentum and kinetic energy of Motion about a point, inertial tensor and the moment of inertia, Eigenvalues of Inertial tensor and the principal axis transformation, methods of solving rigid body problems and Euler's equations of Motion, torque-free Motion of a rigid body. Heavy symmetrical top with one point fixed.

Unit-2 **10 hours**

HAMILTONIAN FORMULATION: Calculus of Variations and Euler-Lagrange's Equation, Brachistochrone Problem, Hamilton's Principle, Extension of Hamilton's Principle to Nonholonomic Systems, Legendre Transformation and the Hamilton Equations of Motion, Physical Significance of Hamiltonian, Derivation of Hamilton's Equations of Motion from a Variational Principle, Routh's Procedure, Principle of Least Action

Unit-3 **10 hours**

CANONICAL TRANSFORMATIONS: Canonical Transformation, Types of Generating Function, conditions for canonical transformation, Integral Invariance of Poincare, Poisson Bracket, Poisson's Theorem, Lagrange Bracket, Poisson and Lagrange Brackets as Canonical Invariant, Infinitesimal Canonical transformation and Conservation Theorems, Liouville's Theorem Hamilton Jacobi Theory: Hamilton-Jacobi Equation for Hamilton's Principal Function, Harmonic Oscillator and Kepler problem by Hamilton-Jacobi Method, Action-Angle Variables for completely Separable System, Kepler Problem in Action-Angle Variables

Unit-4 **10 hours**

SMALL OSCILLATION: Problem of Small Oscillations, Example of linear triatomic molecule, and two coupled Oscillator, General Theory of Small Oscillations, Normal Coordinates and Normal Modes of Vibration

Test Books:

1. Classical Mechanics- by H. Goldstein (Addison-Wesley)

Reference books:

1. Classical Mechanics by S. N. Biswas, Books and Allied Publisher Ltd.
2. Classical Mechanics by J.C. Upadhyay, Himalaya Publishing House.
3. Classical Mechanics by Landau and Liftshitz (Butter Worth)

Sub Code: PHY-C103	Computer Programming and Numerical Analysis	
Semester:1	**Credit:4**	**Core Course**
Pre-requisites: Basic knowledge of Computer, Mathematical Physics		
Course outcomes: ✓ To understand the importance of computer applications in Science and engineering. ✓ To learn and understand basic computer language FORTRAN 77. ✓ To compute and develop algorithms for the Solution of science and engineering problems.		

Unit -1 **12 hours**

FORTRAN 77: Character, Data types, expressions, statements, input and output commands, do loop, condition and dimension statement, character and data management, array manipulations, subprogram, and subroutine.

Unit -2. (Only Programming) **14 Hours**

FORTRAN Programs: Evaluation of series (Sin(x), Cos(x), tan(x), Log(x), $e^{\pm x}$, $\tan^{-1}(x)$ functions etc.), Matrix manipulation, finding the root of an equation by Newton-Raphson method, Numerical integrations by trapezoidal and Simpson method, finding prime numbers, Arrangement of numbers (increasing and decreasing order), interpolation (Newton's and Lagrange's method), Runga-Kutta method and similar other problems.

Unit -3 **14 hours**

Solution of simultaneous linear equations, Gaussian elimination, Pivoting, Iterative Method, Matrix Inversion, Root of a transcendental equation by Newton-Rapson Method, Least square fitting. Eigenvalues and eigenvectors of matrices, power and Jacobi method.

Unit -4 **14 hours**

Finite Differences, Interpolation with equally Spaced and unevenly spaced points (Newton's and Lagrange's method), Forward and Backward Interpolation, Extrapolation, Numerical Integration by trapezoid and Simpson's rule, Solution of first and second order differential equation using Runge-Kutta (RK-4) method.

Textbooks:

1. Fundamentals of Computers by V. Rajaraman, Prentice Hall of India Ltd Publishers.
2. Fortran 77 and Numerical Methods by C Xavier, New Age International (P) Ltd Publishers.
3. Numerical Methods in Science and Engineering by S. Rajasekaran, S.chand

Reference Books:

1. Numerical Mathematical Analyses by J. B. Scarborough, Oxford and IBH Publishing Company
2. Numerical methods for engineering and scientific computation by M K Jain (Wiley Eastern
3. Numerical Methods for Scientific and Engineering Computation by MK Jain, SRKIyengar andR Jain, New Age International (P) Ltd Publishers.

<table>
<tr><td>Sub Code: PHY- C104</td><td colspan="2">Quantum Mechanics -1</td></tr>
<tr><td>Semester:1</td><td>Credit:4</td><td>Core Course</td></tr>
<tr><td colspan="3">Pre-requisites: Basic Mathematical Physics</td></tr>
<tr><td colspan="3">Course Outcomes:
✓ To apply quantum mechanics to the dynamics of a single particle in one-, two andthree-dimensional potential fields
✓ To strengthen the student's analytical abilities and help them apply them in different branches of physics compactly.</td></tr>
</table>

Unit –1 **14 Hours**

GENERAL PRINCIPLES OF QUANTUM MECHANICS:

Postulates of Quantum Mechanics and meaning of measurement, Operators and their expectation values, Dirac Notations,Linear vector space, Ket and Bra vectors, Scalar product of vectors and their properties, Dirac delta function, linear operators, Adjoint operators, Unitary Operators, Expectation values of dynamical variables and physical interpretation of Hermitian operators, Eigen values and eigen vectors, orthonormality of eigenvectors, probability interpretation, Degeneracy, Schmidt methodof orthogonalization, Expansion theorem, Completeness and closure properties of the basis set, Coordinate and momentum representations, compatible Incompatible observables, Commutator algebra, uncertainty relation as a consequence of non- commutability, minimum uncertainty wave packet, Representations of Ket and Bra vectors and operators in matrix form, Unitary transformation of basis vectors and operators.

Unit –2 **12 Hours**

QUANTUM DYNAMICS:

Time evolution of quantum states, Time evolution operator and its properties, Schrödinger, Heisenberg and Interaction picture, Equations of Motion, Operator method solution of Harmonic oscillator problem, Matrix representation and time evolution of creation and annihilation operators.

Unit-3 **14 Hours**

ROTATION AND ORBITAL ANGULAR MOMENTUM:

Rotation Matrix, Orbital angular momentum operators as generators of rotation, Lx, Ly, Lz and L^2 and their Commutation relations, Raising and Lowering operators (L+ and L-), Lx, Ly, Lz and L^2 in Spherical Polar coordinates, Eigen values and Eigen functions of Lz and L^2 (operator method), Matrix representation of Lx, Ly, Lz and L^2.

Unit –4 **12 Hours**

SPIN ANGULAR MOMENTUM:
Spin ½ particles, Pauli spin matrices and their properties, Eigen values and Eigen functions, Spin and rotations. Total angular momentum: Total angular momentum J, Eigenvalue problem of Jz and J^2, Angular momentum matrices, Addition of angular momentum and C. G. coefficients for the states with (i) j_1 = ½ and j_2 = ½ (ii) j_1 = 1 and j_2 = ½.

Textbooks:
1." Quantum Mechanics: Concepts and Applications" by NouredineZettile John Wileyandsons.

Reference Books:

1. "Quantum Mechanics", L.I. Schiff L.I 3rd Ed, McGraw Hill Book Co.
2. "Quantum Mechanics"E. Merzbacher , 2nd Ed., John Wiley &Sons.
3. , "Quantum Physics", S.Gasiorowicz John Wiley.
4. "A Text Book of Quantum Mechanics" by P.M. Mathews. and Venkatesan, Tata McGraw Hill.
5. Introduction to Quantum Mechanics, by D.J.Griffiths ,2nd edition ,Pearson Publications

<table>
<tr><td>Sub Code: PHY- C105</td><td colspan="2">Vedanta Philosophy in Modern Physics Perspective</td></tr>
<tr><td>Semester:1</td><td>Credit:4</td><td>Core Course</td></tr>
<tr><td colspan="3">Pre-requisites: Basic knowledge of Sanscrit and Vedas</td></tr>
<tr><td colspan="3">Course Outcomes:
✓ Recreation of Ancident Indian Knowledge System to Younger Generastion
✓ To motivate students for research on Vedanta Philosophy of Modern Physics</td></tr>
</table>

UNIT-I **12 Hour**

Philosophy and Science: Interactions and Associated processes in nature: Fundamental processes, Fundamental Interactions: Quanta, Particles and Environment; Human experiences and Behavioral Science.

Modelling: Basic of Vedanta Philosophy: Nature and its Description: Viewpoint of Objective Science, Viewpoint of Philosophy, Viewpoint of other Philosophy.

UNIT-II **12 Hour**

PAtomic model of Human Being Introduction. Atom-type model of Human Being, Domains of Physics and Philosophy, Patrons of physics, Applications of the Model. Models for Elementary Particles, Models for Atomic Nucleus, Models for Atoms, Models for Molecules, Models for Gases, Liquids and Solids, Models for Astrophysics and Cosmology, Underlying Forces and interactions, Conservation laws.

UNIT-III **12 Hour**

Generalized Hamiltonian Principle and the Derivation of Space-Time-Consciousness Evolution Equations for EP-Matter: Conscious Action: The case of Real Lagrangian: The case of Complex Lagrangian, Human Perception of Worldly Objects, Dreaming and Imagination as Examples of EP- actions, Quantum Measurement as an Example of EP-actions.

UNT-IV **14 Hour**

Some Exotic Phenomena in the Realm of Human Behavior: An illustrative Analogy, A Brief Survey of Exotic Phenomena, Explanation Based on Western thinking, Explanation Based on Patomic model of Vedic Science

Textbook: R.S. Kausal, D.K. Printworld (P) Ltd. (Publishers of Indian Traditions)

Sub Code: PHY- P106	**Computer Programming and Numerical Analysis (Laboratory work)**	
Semester:1	**Credit:4**	**Core Course**
Pre-requisites: Basic knowledge of computer		

Course Outcomes:

- ✓ To learn and practice basic computer language FORTRAN 77.
- ✓ To program different methods associated with Physics and Engineering

1. Numerical integration by trapezoidal method
2. Numerical integration by Simpson method
3. Solution of first and second order differential equation by RungaKutta Method Matrix addition, subtraction, multiplication and manipulation
4. Matrix inversion
5. Finding the roots of an equation by the Newton-Rapson method
6. Least square fitting of linear parameters
7. Determination of prime numbers.
8. To arrange a set of numbers in increasing or decreasing order
9. The sum of AP and GP series, Sine and Cosine series
10. Factorial of a number
11. Evaluation of log and exponentials by summing of series
12. Any other suitable experiments.

Second Semester

Sub Code: PHY- C201	Classical Electrodynamics	
Semester:2	**Credit:4**	**Core Course**
Pre-requisites: Basic Mathematical Physics, (ii) Classical Electricity and Magnetism.		
Course Outcomes: ✓ To emphasize electric and magnetic radiation field phenomena and Bremsstrahlung radiation in a Coulomb field and Cherenkov radiation, ✓ Electromagnetic Scattering.		

Unit –I **14 hours**

a. **Covariant formulation of electrodynamics:**

Lorentz transformation; Scalars, vectors and Tensors; Maxwell equations and equations of continuity in terms of Aμ and Jμ; Electromagnetic field tensor and its dual;

Covariant forms of Maxwell's equations include Lagrangian for a charged particle in the presence of an external electromagnetic field and Maxwell's equation as Euler-Lagrange equations.

b. The Inhomogeneous Wave equation:

Wave equations for potentials, Solution by Fourier analysis, Radiation field, Radiation energy, Hertz potential, Computation of radiation fields by Hertz method, electric dipole radiation, multipole-radiation.

Unit –II **12 Hours**

a) **Lienard-Wiechart potential and Field of a uniformly moving electron:** Lienard-Wiechart potential, Fields of a charge in uniform Motion, Direct Solution of the wave equation, Convection potential, Virtual photon concept.

(b) Waveguides, Propagation of electromagnetic waves in rectangular waveguides.

Unit –III **14 Hours**

Radiation from Accelerated Charges:

Radiation from an accelerated charge, Fields of accelerated charge radiation at low velocity, Case of velocity parallel to acceleration, Radiation from circular orbits, Radiation with no restrictions on the acceleration or velocity, Classical cross-section for bremsstrahlung in aCoulomb field, Cherenkov radiation.

Unit –IV **14 Hours**

Radiation, Scattering and Dispersion:

Radiative damping of a charged harmonic oscillator, forced vibrations, scattering by an individual free electron, scattering by a bound electron, absorption of Radiation by an oscillator, equilibrium between an oscillator and a radiation field, the Effect of a volume distribution of scatters,scattering from a volume distribution, Rayleigh scattering, the dispersion relation.

Text Book:

1. "Classical Electricity and Magnetism" by Wolfgang K.H.Panofsky and Melba Philips , Second Edition.

Reference books:

1 "Classical Electrodynamics", Jackson J D, John Wiley.
2. 'Introduction to Electrodynamics", Griffiths D J, Prentice Hall.

Sub Code: PHY-C202	Statistical Mechanics	
Semester:2	**Credit:4**	**Core Course**
Pre-requisites: Basic laws of thermodynamics		

Course Outcomes:

- ✓ *To* develop a working knowledge of statistical mechanics.
- ✓ To learn the statistical interpretation of phenomena like ensembles, ideal systems, photon gas, Low-temperature physics and their applications, Bose-Einstein condensation, and phase transition.
- ✓ To explore its applications in other branches of physics like material science and the physics of condensed matter.

Unit -1 **12 Hours**

Classical Statistical Mechanics: Postulates of classical statistical mechanics, Lowville's theorem micro-canonical ensemble, derivation of thermodynamics, equipartition theorem, Classical ideal gas, Gibb's paradox, .canonical ensemble, energy fluctuation in canonical ensemble, grand canonical ensemble, density fluctuation in grand canonical ensemble, equivalence of canonical and grand canonical ensemble.

Unit -2

12 Hours

Quantum Statistical Mechanics: Postulates of quantum statistical mechanics, density matrix, Liouville's theorem, ensembles in quantum statistical mechanics, third law of thermodynamics, Ideal gases in micro-canonical ensemble. Particle in a box, MB, BE and FD distributions—theIdeal Gases in Grand Canonical Ensemble, Equation of state of Ideal Bose Gas, Fermi Gas.

Unit -3

12 Hours

Fermi Gas: The Equation of state of an Ideal Fermi gas, High temperature and low Densities, Low temperature and High Densities, Theory of White Dwarf Stars, Pauli par magnetism.

Unit -4 **12 Hours**

Bose Gas: Ideal Bose gas, Photon, Planck's law, Bose-Einstein condensation. 1^{st}-order and 2^{nd}-order phase transitions, Ginzburg Landau theory of phase Transition, Ising model (one-dimensional Ising model)

Text Book:

1. Statistical Mechanics – K. Huang, Wiley India

Reference books:

1. Statistical Mechanics – Landau and Lifshitz, Butterworth
2. Statistical Mechanics- R. K. Patheria, P.D. Beale 3rd Ed, Butter Worth-Heinemann
3. Fundamental statistical and thermal Physics- F. Reif, Tata Mc Graw-Hill Edition
4. Elementary statistical mechanics, C. Kittel, Dover Publication

<table>
<tr><td>Sub. Code: PHY-C203</td><td colspan="2">Basic Solid State Physics</td></tr>
<tr><td>Semester: 2</td><td>Credit : 4</td><td>Core Course</td></tr>
<tr><td colspan="3">Pre-requisites: Crystal structure, Bragg's Diffraction, Reciprocal lattice space</td></tr>
<tr><td colspan="3">Course Outcomes:
✓ To understand the different bond mechanisms.
✓ To understand the evolution of phonon and its importance in electrical and thermalproperties
✓ To understand FEM and NFEM.
✓ To understand different classes of solids.</td></tr>
</table>

Unit-1 **10 hours**

CRYSTAL BINDING: Crystals of inert gases, Ionic crystals, covalent crystals, Metals Lattice Dynamics-Vibrations of a monoatomic linear chain, Vibration of a diatomic linear chain, Dispersion relations, Acoustic and Optic modes, Long-wavelength limits.

Unit-2 **10 hours**

SPECIFIC HEAT OF INSULATORS AND FEM: Phonon heat Capacity, Debye model for the density of states, Debye T 3 law, Einstein's theory of the specific heat Free Electron Fermi gas-Energy levels inone-dimension, Effect of temperature on the Fermi-Dirac distribution function, Free electron gasin three dimensions, Heat Capacity of the electron gas, Electrical conductivity and Ohm's law, Motion in magnetic fields, Static magneto-conductivity tensor, Hall effect, Thermal conductivity of metals, Wied man- Franz Law.

Unit-3

NEARLY FREE ELECTRON MODEL: Nearly free electron model, origin of the energy gap, Bloch functions, Kronig-Penney model, Wave equation of electron in a periodic potential, restatement of Bloch theorem,Solution of the central equation, approximate Solution near a zone boundary, number of orbitals in a band, metals and insulators.

Unit-4

SEMICONDUCTOR CRYSTALS: Band gap, Holes, effective mass, intrinsic carrier concentration, intrinsic mobility, impurity conductivity, donor states, acceptor states, thermal ionization of donors and acceptors. Defects, Impurities as defects, TM and RE impurities, Multiband Structure, Energy dispersion, Semiconductor and Magnetism, Compound Semiconductors, Different groups of semiconductors, Introduction to Diluted Magnetic Semiconductors. Moore's law, MR-logic Elements and Application.

Reference Books:

1. Introduction to the theory of Solid State Physics by J. D. Patterson (Addison-Wesley,1971)
2. Solid State Physics by N. W. Ashcroft and N. D. Mermin, (Harcourt Asia P.T.E. Ltd.)
3.Physics of Condensed Matter by Prasanta K.Misra (Academic Press, 2010)

	QUANTUM MECHANICS-II	
Semester:204	**Credit:4**	**Core Course**
Pre-requisites: Basic knowledge in Quantum mechanics-1 and Mathematics to handle model description based on physical laws		
Course Outcomes: ✓ To learn the properties of molecules and atoms and their constituents—electrons, protons, neutrons, and other more esoteric particles such as quarks and gluons.		

Unit-1 **12 Hours**

Motion in a spherically symmetric field:

The hydrogen atom, Reduction to the equivalent one-body problem, radial equation, Energy eigenvalues and eigen functions, Degeneracy, Radial probability distribution, free-particle problem,Expression of plane waves in terms of spherical waves, Bound states of a 3-D square well.

Unit-2 **12 Hours**

Approximate methods:

Stationary perturbation theory; Rayleigh Schrodinger method for non-degenerate Case; first and second order perturbation, a harmonic oscillator, general theory for the degenerate Case, removal of degeneracy, linear Stark Effect, average Zeeman effect**.**

Unit-3 **12 Hours**

. **Variationalmethod**: Ground State, First Excited State and Second Excited State of One-Dimensional Harmonic Oscillator, Ground State of H-atom and He-atom.

W. K. B. method: Connection formulas, Bohr-Sommerfeld quantization rule, Harmonic oscillatorand cold emission**.**

Time-dependent perturbation theory:

Transition probability, constant and harmonic perturbation, Fermi Golden rule

Unit-4 **12 Hours**

Scattering amplitude and scattering cross-section:

Born approximation, application to Coulomb and screened Coulomb potentials.

Partial wave analysis for Scattering; optical theorem, scattering from a rigid sphere, resonantScattering from a square well potential.

Identical particles, Symmetric and antisymmetric wave function, Scattering of identical particles.

Textbooks:

1." Quantum Mechanics: Concepts and Applications" by NouredineZettile John Wiley and Sons.

Reference Books:

"Quantum Mechanics", L.I. Schiff 3rd Ed, McGraw Hill Book Co.
"Quantum Mechanics" E. Merzbacher, 2nd Ed., John Wiley &Sons.
"Quantum Physics", S.Gasiorowicz John Wiley.
"A Text Book of Quantum Mechanics" by P.M. Mathews . and Venkatesan, Tata McGraw Hill.
Introduction to Quantum Mechanics, by D.J.Griffiths,2nd edition,
Pearson Publications

<table>
<tr><td>Sub Code: PHY- P205</td><td colspan="2">Optics (Laboratory work)</td></tr>
<tr><td>Semester:1</td><td>Credit</td><td>Core Course</td></tr>
<tr><td colspan="3">Pre-requisites: Basic knowledge of Optics</td></tr>
<tr><td colspan="3">Course Outcomes: To apply the principle of optics in experiments.</td></tr>
</table>

1. Experiments with optical bench: Biprism Straight edge and narrow wire
2. Experiments with spectrometer: Single and Double Split
3. Experiments with Michelson interferometer: Determination of A and α Thickness of mica sheet
4. Fabry Perot interferometer
5. Polarization Experiments Babinet compensator Edsar-Butlerbands Quarter wave plate Mallus Law Study of elliptical polarized light
6. Constant Deviation Spectrography Calibration Zeeman effect
7. Babinet Quartz Spectrography
8. Any other suitable experiments
9. Any other experiments that may be set up from time to time

Course No. PHY- VAC206A	Course Name: **Materials Characterization**	
Semester: II	**Non-Credit**	**V A C**
Pre-requisites:		
Course Outcome: The course aims to provide theory and hands-on training on the instrument facilities at Berhampur University. This will help the students understand the spectroscopic techniques required to characterize materials synthesized in the laboratory.		

Chapter/ Unit	**Contents**	Hours/ Semester
1	**UV-visible spectroscopy**: Baseline correction with a suitable solvent, blanking the instrument, determination of suitable Concentration, quantitative measurement of samples of different concentrations. Kinetic measurement of reaction to determine rate constant, spectral measurement of different compounds, data export in various formats and plotting in origin. Other tips & things to watch out for when measuring particle size: Band gap measurement using Tauc plot.	10
2	**Photoluminescence spectroscopy**: Determination of excitation and emission peak for unknown sample, choosing the right filter for correct measurement, using the solid sample as well as solution sample, measurement in fluorescence and phosphorescence mode for lanthanide-doped sample as well as organic molecules. Lifetime measurement and lifetime calculation in single and double exponential plotting in origin. Data export and plotting in origin. Other tips in PL measurement.	10
3	**X-Ray Diffraction Studies**: Basic principles, Baseline correction, Crystal structure determination, Calculation of crystallite size from XRD data, Insertion of negative hkl indices in XRD graph, Calculation of d-spacing, lattice constant, crystalline mode, microstrain, dislocation density, Modified W-Hplot for crystallite size/ microstrain and energy density.	10
4	**Magnetic susceptibility Measurement**: Elementary idea about magnetic properties of metal complexes, Diamagnetism, Para magnetism, Magnetic susceptibility and its measurement, Ferromagnetism, Ferrimagnetism and Anti-ferromagnetism.	10
Total		40

Sub Code: PHY-VAC206B	DFT and Materials Modelling	
Semester:2	**Non-Credit:**	**VAC**
Pre-requisites: Quantum Physics, Mathematics and Computation		

Course Outcomes:

1. To understand a single atom and its behaviour independently.
2. To understand the evolution of different properties dependent on densityfunctional.
3. To understand different approximations leading to better exchange-correlation.
4. To understand the implementation of DFT on Quantum Expresso and codes
5. To evaluate numerically different physical properties.

Unit-I **10 Hour**

Preliminaries: Atomic model, The hydrogen atom, Solution of Schrodinger Equation, Electron wave functions and energies, Probability distribution. Multi-electron atoms, Hartree-Fock Theory, Free electron model(FEM), Nearly free electron model(NFEM)

Unit-II **10 Hour**

The Schrodinger Equation, Density Functional Theory—From Wave Functions to Electron Density, Exchange–Correlation Functional, Localized and Spatially Extended Functions, Wave-Function-Based Methods, Hartree–Fock Method, Beyond Hartree–Fock. DFT Calculations for Simple Solids, Periodic Structures, Supercells, Lattice Parameters, Face-Centered Cubic Materials, Hexagonal Close-Packed Materials, Crystal Structure Prediction, Phase Transformations,

Unit-III

Nuts and Bolts of DFT Calculations: Reciprocal Space and k Points, Plane Waves and the Brillouin Zone, Integrals in k Space, Choosing k Points in the Brillouin Zone, Metals—Special Cases in k Space, Summary of k Space, Energy Cutoffs, Pseudopotentials, Numerical Optimization, DFT Total Energies-An Iterative Optimization Problem, Geometry Optimization, Internal Degrees of Freedom, Optimizing Supercell Volume and Shape, Electronic Structure and, Electronic Density of States, Local Density of States and Atomic Charges, Magnetism

Unit-IV

Applications: **Quantum Espresso**, Materials Cloud, Examples: **Silicon:** Self-consistent Field, Writing the input, Running the code, Reading the output, lattice constant and bulk modulus of silicon, Bands, **Graphene:** Compute the band structure.

References: Books

1. A Practical Introduction to Density Functional Theory By L. Rademaker
2. Electronic Density Functional Theory Recent Progress and New Directions by John F. Dobson Giovanni Vignale and Mukunda P. Das.

Third Semester

Sub Code: PHY- C301	Relativistic Quantum Mechanics & Field Theory	
Semester:3	**Credit:4**	**Core Course**
Pre-requisites: Quantum Mechanics, Special theory of relativity, Mathematical Physics and Electrodynamics.		
Course Outcomes: ✓ To study the Effect of relativity on quantum mechanics and to develop the formulationfor Relativistic systems along with the quantization principle. ✓ To introduce the basic concept of Quantum field theory to understand the dynamics of relativistic systems through creation and annihilation operators		

Unit-1 **12Hours**

A brief introduction to Relativistic quantum mechanics, the Klein-Gordon equation and its drawbacks, Charge and current densities, Positive and negative energy states, and Klein-Gordon equation in the Presence of Electromagnetic Field. Dirac Equation, Free particle Dirac equation, Properties of the Dirac matrices, Continuity Equation, Spin of the electron. Gordon Decomposition of Dirac Hamiltonian.

Unit -2 **12 hours**

Plain wave solutions of the Dirac Equation, Normalization of the wave functions, Dirac Hole Theory, Dirac equation in an electromagnetic field, its non-relativistic correspondence, magnetic moment, Dirac equation in the presence of Spherically symmetric potential, Dirac Equation in Presence of Central force, spin-orbit coupling, Covariant form of the Dirac equation, Proof of its Lorentz covariance, Properties of the gamma-matrices. Bilinear covariant.

Unit -3 **10 hours**

Concept of fields, Classical field equation, Noether's theorem and conservation laws, Gauge invariance and charge conservation, Creation, Annihilation and number operators.

Unit -4 **14 hours**

Field Quantization: (a) neutral scalar meson field, (b) charged scalar meson field, and (c) Dirac field.

Textbooks and reading materials:

1. Relativistic quantum field theory by J.D. Bjorken and SD. Drell(McGraw-Hill Publisher).
2. Lectures on Quantum Field Theory, Ashok Das, (World Scientific Publishing Co.)
3. Lahiri A, Pal P.B., A First Book of Quantum Field Theory(Narosa Publishing House)
4. Quantum Mechanics and Field Theory by BK. Agarwal (Asia Publishing House

<table>
<tr><td>Sub Code: PHY-C302</td><td colspan="2">Electronics</td></tr>
<tr><td>Semester:1</td><td>Credit:4</td><td>Core Course</td></tr>
<tr><td colspan="3">Pre-requisites: P.N. Junction. Network Analysis (Kirchhoff Laws)</td></tr>
<tr><td colspan="3">Course Outcomes:
✓ To familiarize the student with basic analog and digital electronic components.
✓ Understand DC analysis and AC models of semiconductor devices
✓ Apply concepts for the Design of Amplifier
✓ Understand number representation and conversion between different representations in digital electronic circuits.
✓ Analyze logic processes and implement logical operations using combinational logic circuits.</td></tr>
</table>

Unit-1 **12 Hour**

Network Analysis: Superposition principle Thevenin and Norton Theorems, BJT, FET, MOSFET: characteristic, biasing-parameter analysis**.** Feedback Circuits.

Operational Amplifiers: The differential amplifier, DC and AC signal analysis, integral amplifier, rejection of standard mode signals, CMMR, The operational amplifier, input and output impedances, Application of operational Amplifiers unit gain buffer, summing, integrating amplifier, Comparator, Operational amplifier as a differentiato**r.**

.

Unit -2 **8 Hour**

Oscillator circuits: Feedback criteria for oscillation, Nyquist criterion, Phase shift, Wien-Bridge oscillator, Crystal controlled oscillator

Unit-3 **12 Hour**

Digital Circuits: Logic fundamentals, Booleantheorem, logic gates: AND, OR, NOT, NOR, NAND XOR, and EXNOR.RTL, DTL and TTL logic, Flip-flop, RS-and JK-Flip flop, A/D and D/A Convertors

Unit-4 **12 Hour**

Optoelectronics Device:

Principle of optical sources, Source material, Choice of materials, Internal and external quantum efficiency of LED, Structures, Types of LED: Surface-emitting LED, Edge emitting LED, Modulation capability, emission pattern, power bandwidth product, laser Diode Modes, Threshold condition, resonant frequency, Laser Diode Structure, Brief description of principle of optical detectors, Photomultipliers PIN and APD configuration, Solar Cell

Textbooks and reading materials

1. Electronic fundamental and application by J.D. Ryder, PHI, Learning Pvt Ltd.

2. Electronics: Circuits and Analysis, D.C.Dubey, Alpha Science

3. R.P.Khare, Fiber Optics and Optoelectronics, Oxford University Press

References:

1. Foundation of electronics – Chattopadhyay, Rakshit, Saha and Purkait,
New Age International publisher
2. Electronics principles-Albert Malvino, Tata Mc Graw-Hill Edition
3. Modern Digital Electronics-R.P Jain, Tata Mc Graw-Hill Edition

Sub Code: PHY-C303A	Condensed Matter and Material Physics	
Semester:3	**Credit:4**	**Core Course**
Pre-requisites: Basic knowledge in solid state physics, Classical mechanics, Quantum mechanics and elementary mathematics to handle model description based on physical laws		
Course Outcomes: ✓ To provide an introduction to the physics of condensed Matters ✓ To acquaint them with areas like quantization of lattice vibrations, electron-electron interaction, superconductivity and Advanced Superconductivity.		

Unit-1 **12 Hours**

Quantization of lattice vibration: Phonons, normal coordinate transformation, creation and annihilation operators. Methods of band calculation: The tight binding method, OPW, and pseudopotential methods. Fermi Surface, de Haas-van Alphen effect. Transport theory- Boltzmann equation, relaxation time approximation, electrical conductivity and thermal conductivity.

Unit-2 **12 Hours**

Electron-electron interaction: Hartree approximation, Hartree-Fock approximation, Hartree-Fock theory for jellium model. Density functional theory-general formulation, Local Density Approximation. , General formalism of Screening, Thomas-Fermi Approximation.

Unit-3 **12 Hours**

Superconductivity: Occurrence of superconductivity, Meissner effects, Type- I and II superconductors, energy gap, Isotope effect, Theoretical survey: Thermodynamics of superconducting transition, London equations, coherence length, Qualitative ideas about the BCS theory, Single particle tunneling, Josephson effect.

Unit-4 **12 Hours**

Advanced Superconductivity: Electron-phonon interaction, Microscopic theory of superconductivity, Quasi electrons, Cooper pairs, BCS theory, Ground State ofsuperconducting electron gas, elementary ideas of high Tc superconductors

Text Book:

1. Physics of Condensed Matter By Prasanta K. Misra(Academic Press, 2010)
2. Quantum Theory of Solid State by J.Callaway(Academic Press)

Reference books:

1. Principles of the theory of solids, J. M. Ziman(Cambridge and University Press)
2. Solid State Physics by C. Kittle (John Wiley and Sons, Ins Singapore)
3. Introduction to the theory of Solid State Physics by J. D. Patterson (Addison- Wesley,1971)
4. Intermediate Quantum Theory of Crystalline Solids by Alexander O.E. Animalu (Prentice Hall of India, 1978)

Sub Code: PHY-E303B	Nuclear Science-I	
Semester:1	**Credit:4**	**Elective course**
Pre-requisites: Basic Nuclear Science		

Course Outcomes:

- ✓ To understand the advance of Nuclear Physics

Unit-1 **12 Hour**

Rotation of Matrix and Tensor: Rotational invariance in three dimensions, eigen values a eigen functions of angular momentum operators, explicit representation of the rotation matriceAddition of angular momenta, Clebsch-Gordon coefficients, irreducible spherical tensor, matrelement of tensor operators, Wigner-Eckart theorem

Unit-2 **12 Hour**

Optical model: Optical model, deuteron stripping and pick-up reaction, Elementary ideas Brueckner theory

Unit-3 **12 Hour**

Collective Model: Collective Vibrational modes of a spherical nucleus, collective oscillationquadruple deformation, Expression for moment of inertia.

Unit-4 **12 Hour**

Rotational Spectra: Rotational spectra of even-even nuclei, coupling of a particle and collectimotion, electric quadruple moments, magnetic dipole moments

Textbooks:

1. Nuclear Physics by R.R. Roy and B.P. Nigam, John Wiley

Reference Books:

2. Physics of the nucleus by M.A. Preston, Addison Wesley.
3. Nuclear Physics by S.S.M. Wong, Prentice Hall.
4. Introduction to Nuclear Physics by H. A. Enge, Addison Wesley
5. Structure of the Nucleus by M. A. Preston and R K Bhaduri, Addison Wesley

Sub Code: PHY- P306	**Modern Physics** **(Laboratory work)**	
Semester:1	**Credit:4**	**Core Course**
Pre-requisites: Basic knowledge of Modern Physics		
Course outcomes: ✓ To design and analyze experiments in Modern Physics		

1. Determination of e/m by
I) Braun tube method
II) Magnetron Valve method
2. Determination of Planck's constant(h) by Photo-electric effect methods
3. Measurement of velocity of light by Lecher wire
4. GM counter experiments:
I) Characteristics of the Geiger tube
II) Inverse Square Law.
III) Absorption coefficient of the Aluminium foil.
5. Characteristics of Diode and Zener diode.
6. Study logic gates AND, OR, NOT, NAND, NOR, EXOR.
7. Making AND, OR, NOT Gates using NAND Gates.
8. Verification of Boolean Algebra.
9. Verification of Dual Nature.
10. Characteristics of FET (Field Effect Transistor).
Any other experiments that may be set up from time to time

Sub Code: PHY-E301	Fiber Optics and Optoelectronics	
Semester:4	**Credit:4**	**Elective Course**
Pre-requisites: Basic Physics at the higher secondary level		

Course outcomes:
- ✓ The objective of this course is to familiarize students the role of fiber optics inday today applications.
- ✓ To provide basic knowledge for designing simple experiment using L.E.D.,Fiber and Detector

Unit- 1 **12 Hours**

Optical fiber structure: Step Index Fiber, Graded Index Fiber, Transmission oflight through cylindrical waveguide by using electromagnetic theory. Single mode and multimode fibres, modal concept, step index and graded index fiber modes, V-number, power flow in Step Index fiber. Different types of fiber, Elementary idea on Fiber Materials, Fabricationmethod: Double Crucible Method, fiber optic Cables, Photonic crystal fiber and Fiber Bragg Grating

UNIT-2 **10 Hours**

Signal degradation in Optical Fiber: Attenuation, Absorption, bending Loss, Scattering Loss, Core Cladding losses, dispersion losses, Material dispersion, waveguide dispersion, Modal Dispersion, Signal distortion in single-mode fibers, Design of optimization of single mode fibers. Dispersion shifted, and Dispersion flattened fiber.

Unit-3 **08 Hours**

Connector, Couplers and Splices: Connector and splice, losses during coupling between source fibers, fiber to fiber, Lensing scheme for coupling improvement, Joint losses, multimode fiber joints, single mode fiber joint, Fusion splice, Mechanical Splices, Multimode splices, connector and coupler

Unit-4 **12 Hours**

Optical Source and Photodetector: Principle of optical sources, Source material, Choice of materials, Integral and external quantum efficiency of LED, Structures, Types of LED:Surface-emitting LED, Edge emitting LED, Modulation capability, emission pattern, power bandwidth product, laser Diode Modes, Threshold condition, resonant frequency, Laser Diode Structure, Brief description of principle of optical detectors, Photomultipliers PN, PIN and A.P.D. configuration, Photodetector noise, Noise sources, SNR, Detector response time

Textbooks:

1. R.P.Khare, Fiber Optics and Optoelectronics,Oxford University Press
2. AjoyGhatak and K.Thyagarajan,An Introduction to Fiber Optics,

Cambridge University Press
Reference Books:
3. G. Keiser, Optical Fibre Communications, McGraw-Hill.

4. J.M.Senior, Optical Fibre Communications Principles and Practice, PHI.

OR

Sub Code: PHY-VAC305A	**Atomic and Molecular Spectra**	
Semester:4	**Non-Credit**	**VAC**
Pre-requisites: Basic knowledge in Quantum Mechanics-I, Modern Physics, Basic Nuclear Physics		
Course outcomes: ✓ To understand different atomic models and their developments ✓ To learn the behaviour of atom and molecules in the presence of electric and magneticFields and molecular Vibration. ✓ To understand atomic and molecular spectra		

Unit-1 **12 Hours**

Revision of Hydrogen atom; Bohr-Summerfield Theory, quantum theory of hydrogen atom, wave functions, orbital and spin angular momentum, magnetic dipole moment, spin orbit interaction, fine structure, spectroscopic term and notation. Hydrogen fine structure. Spectrum of Helium.

Unit-2 **12 Hours**

Hartrees' central field approximation, atomic orbital and Hund's rule. LS and JJ Coupling

Unit-3 **12 Hours**

Normal and Anomalous Zeeman effect, Explanations of Zeeman Effect in some transitions. Paschen-Bach Effect Stark-Effect: Weak Field and strong Field Stark effect in hydrogen. Hyperfine structure and isotope effect, Nuclear Spin and hyperfine structure.

Unit-4 **12 Hours**

Types of molecular spectra: Electronic spectra, Vibrational-Rotational spectra, the molecule as a harmonic and non-harmonic oscillator; Pure Rotational Spectra, the molecule as a rigid and non-rigid rotator.The Raman spectra and molecular structure.

Text Book:

1. Atomic and Molecular Spectra: Laser by Raj Kumar
2. Introduction to atomic spectra by H. E. White

OR

Sub Code: PHY-VAC305B	ASTRONOMY AND ASTROPHYSICS	
Semester:3	**Non- Credit:4**	**VAC**
Pre-requisites: Basic knowledge in Quantum Mechanics-I, Modern Physics, Basic Nuclear Physics		
Course outcomes: 1. **To understand Tools of Astronomy and celestial mechanics** 2. **To introduce basic astronomical principles in studying the planets, stars and galaxies.**		

UNIT I: **15 Hours**

Celestial Mechanics and Astrometry: The Celestial Sphere, Positions of stars, Proper motions of stars and planets, Distances of nearby stars.

Tools of Astronomy: Telescopes: Basic Optics, Optical Telescopes, Radio Telescopes, Infrared, Ultraviolet, X-ray, and Gamma-Ray Astronomy – detectors and observatories Gravitational Waves detectors and Neutrino detectors All-Sky Surveys and Virtual Observatories.

UNIT II: **15 Hours**

The Solar System: The Sun, The Physical Processes in the solar system, The Terrestrial and the Giant Planets, Formation of Planetary Systems.

Basic Stellar Parameters: The brightness of the stars, Color-magnitude diagrams (The HR diagrams), The luminosities of the stars, Angular radii of stars, Effective temperatures of stars, Masses and radii of stars: Binary stars, Search for Extrasolar Planets.

UNIT III: **15 Hours**

The Nature of Stars: Spectral classification, Understanding stellar spectra, Population II stars, Stellar rotation, Stellar magnetic fields, Stars with peculiar spectra, Pulsating stars, Explosive stars, Interstellar absorption

UNIT IV: **15Hours**

Our Galaxy And The Interstellar Matter: The shape and size of our Galaxy, Interstellar extinction and reddening, Galactic coordinates, Galactic rotation, Stellar population, Inter-Stellar Medium, The galactic magnetic Field and cosmic

References:

1. Introduction to Stellar Astrophysics, Volume 1, Basic stellar observations and data, By Erika Bohm-Vitense, Cambridge University Press
2. An Introduction to Modern Astrophysics, Second Edition, By Carroll B.W., Ostlie D.A., Pearson Addison Wesley.
3. "Astrophysics for Physicists" by Arnab Rai Choudhuri, Cambridge University Press, 2010
4. Galactic Astronomy: Structure and Kinematics by Mihalas & Binney, W.H. Freeman &Co Ltd; 2nd Revised edition 1981.

Course Outcome:

Learners should be able to:

1. Have knowledge of the expanse of the universe and the nature of the planets, stars and galaxies.
2. Understand how the astronomical observations are done for these celestial objects.
3. Apply mathematical tools and physics laws to understand the nature of planets, stars and galaxies.
4. Use online resources to analyze the data obtained from various astronomical observations.
5. Evaluate the results of this analyses and interpret the nature of the Solar system, variety of stars and galaxies.
6. Create new observational programs or data analyses and interpretation projects in astronomy

Sub Code: PHY-VAC305C	OPTICAL FIBRE SENSOR	
Semester:3	**Non- Credit:4**	**VAC**
Pre-requisites: Basic knowledge in Quantum Mechanics-I, Modern Physics, Basic Nuclear Physics		
Course outcomes: 1. Identify different types of optical sensors and their performance characteristics - Analyze a given sensing requirement and design an appropriate sensor - Realize and implement anoptimal sensing solution for a given requirement		

Course outline

UNIT-1 **12 Hours**

Need for optical sensors • Different types of Sensors • Optical receiver design; noise issues,

UNIT-II **12Hours**

Amplitude Modulated sensors • Lock-in detection, Phase modulated sensors • Phase noise analysis and mitigation; Sensitivity limits, Wavelength modulated sensors •

UNIT-III **12Hours**

Interrogator design, sensitivity limits, Polarization Modulated Sensors

UNIT-IV **12 Hours**

Analysis of current sensor, Distributed Fiber Sensors • Raman & Brillouin Scattering-based sensors.

Reference:

1. R.P.KHARE, Oxford University Press

Fourth Semester

<table>
<tr><td>Sub Code: PHY-E401A</td><td colspan="2">Elementary Particle Physics</td></tr>
<tr><td>Semester:4</td><td>Credit:4</td><td>Elective Course</td></tr>
<tr><td colspan="3">Pre-requisites:
✓ Basic knowledge of Quantum mechanics,
✓ Relativistic QuantumMechanics</td></tr>
<tr><td colspan="3">Course Outcomes:
✓ The main goal of particle physics is to learn about the universe around us.
✓ Over the past half-century, particle physicists have formulated the Standard Model, a beautiful framework that explains the visible universe from the smallest to the largest scales.</td></tr>
</table>

Unit-1 **12 Hours**

Historical introduction to the Elementary Particles, Classification of elementary particles and their interactions: Photons, Leptons, Quarks, Mesons, Baryons. Lepton number, Baryon number, colour quantum number, Strangeness quantum number.

Unit-2 **12 Hours**

Charge independence of nuclear forces, Isospin, Test for isospin conservation, Associated Production of Strange particles, Gell-Mann Nishijima scheme, and conservation laws concerning particle reactions and decays.

Unit-3 **12 Hours**

Unitary Symmetry: SU (2), SU (3), Concept of I-Spin, U-Spin, V-Spin, SU(3) Quark model, The Eight-fold way, Mesons and Baryons in the Octet representation. The Baryon Decouplets, Evidence of color, Gell-Mann–Okubo mass formula**.**

Unit-4 **12 Hours**

Discrete Symmetry:

Parity (P): Parity in quantum mechanics and Field theories, Test of Parity. Time reversal (T): Time reversal in quantum mechanics and Field theories, Test of Time reversal Charge conjugation (C): Additive quantum number, Charge conjugation in field theories, Test of Charge-conjugation. CPT theorem and its consequences

Text Book:

1. "Introduction of Elementary Particles", D.Griffith, John Wiley
2. "Quarks and Leptons" Halzen, F. and Martin, A.D., John Wiley
3. "Gauge theory of Elementary Particle, T.-P. Cheng and L.-F.Li, Physics''Oxford University Press
4. S Gasiorowicz ".Elementary particle physics" by. John Wiley &Sons.
5. Modern Elementary Particle Physics by G.Kane, Addison-Wesley Publishing Company
6. Mark Thomson "Modern Particle Physics" Cambridge University Press.

OR

Sub Code: PHY-E401 B	**General Theory of Relativity (GTR.)**	
Semester:4	**Credit:4**	**Elective**
Pre-requisites: Tensor algebra, Quantum Mechanics		
Course outcomes: ✓ To learn about the advances in the General Theory of Relativity. ✓ It will give the basic knowledge of Gravity as a geometry of space-time, gravitational waves and the formation of astrophysical objects.		

Unit-1 **12 hours**

Special theory of relativity: Lorentz transformations; 4-vectors, Tensors and it's transformation properties, Contraction, Symmetric and antisymmetric tensors; 4-dimensional velocity and acceleration; four-momentum and four-force; Covariant equations of Motion; Relativistic kinematics (decay and elastic Scattering); Lagrangian and Hamiltonian of a relativistic particle.

Unit-2 **12 hours**

The Equivalence Principle, The Weak and Strong Principle of Equivalence, The Equation of Motion in the presence of Gravitational Forces, The affine connection, The Metric Tensor g_{uv} , Relation between Metric Tensor and Affine Connection, The transformation of Affine Connection, Covariant derivatives.

Unit-3 **12 hours**

The Newtonian Limit: Relation between g_{00} and the Newtonian potential, Time Dilation in a Gravitational Field, Redshift of spectral lines, The Solar Red Shift.

Unit-4 **12 hours**

Definition of Curvature tensor, Algebraic Properties of the curvature Tensor, Ricci Tensor and Curvature Scalar, Bianchi identities. Einstein's Field Equations, Energy, Momentum and Angular momentum of gravitation.

Textbooks and reading materials:

1. Special theory of relativity, Robert Resnick (Oxford University)

2. Gravitation and Cosmology by Steven Weinberg (Jon Wiley and Sons) References:

2. Introducing Einstein's Relativity by Ray D Inverno (Clarendon Press)
3. An Introduction to General Relativity and Cosmology by Tail. Chow, (Springer)
4. Principles of Cosmology and Gravitation by M. Berry (Cambridge University)
5. The special theory of relativity, Robert Katz D. Van (Nostrond Company, INC.

<table>
<tr><td>Sub Code: PHY-C402</td><td colspan="2">Basic Nuclear Physics</td></tr>
<tr><td>Semester:3</td><td>Credit:4</td><td>Core Course</td></tr>
<tr><td colspan="3">Pre-requisites: Quantum mechanics (I and II), Electrodynamics, Mathematical Physics</td></tr>
<tr><td colspan="3">Course Outcomes:
✓ To understand the basic properties of Nucleus and Nuclear matter.
✓ To learn and understand Deuteron, Scattering, nuclear energy, and nuclear model.
✓ To understand the application of Quantum mechanics in Nuclear physics and its correlation with Atomic and Particle Physics</td></tr>
</table>

Unit -1 **12 Hours**

Nuclear properties: Nuclear Radius, Nuclear Mass, Binding Energy, Angular Momentum, Parity, Symmetry, Magnetic Dipole Moment and Electric Quadruple Moment.
Two nucleons Bound state problem: Central and non-central force, the Deuteron, tensor forces,magnetic moment and quadruple moment of Deuteron

Unit -2 **12 Hours**

Nucleon scattering problem: n-p scattering at low energy, scattering cross section and Scattering

Length, effective range theory.
Nuclear force: Meson theory of nuclear force, Yukawa interaction

Unit-3 **12 Hours**

Nuclear reaction and resonances, Breit-Wigner formula for s-waves, compound nucleus. Liquid drop model, Bohr-Wheeler theory of fission, nuclear fusion

Unit -4 **12 Hours**

Single particle model of the nucleus, magic numbers, spin-orbit coupling, angular moment and parities of nuclear ground states, magnetic moments and Schmidt lines, Collective model of Bohr and Mottelson.

Text Book:
1. Nuclear Physics by R.R. Roy and B.P. Nigam (John Wiley)
2. Nuclear Physics by D.G Tayal, Himalaya Publishing House
3. Nuclear Physics by SN Ghoshal,S.Chand

Reference books:
1. Physics of the Nucleus by M.A. Preston (Addison Wesley)
2. Nuclear Physics by S.S.M. Wong (Prentice Hall)
3. Introduction to Nuclear Physics by H. A. Enge (Addison Wesley)

Reference books:
1. The Fundamentals of Atomic and Molecular Physics by L.Robert, Springer

Sub Code: PHY-E403	**Project and Seminar**	
Semester:4	**Credit:4**	**PROJECT**
Course outcomes: ✓ The main objective of this course is to work on a mini project, learn how to prepare a research report and present before an audience.		

Sub Code: PHY-E404A	Condensed Matter and Materials Physics	
Semester:4	**Credit:4**	**Elective**
Pre-requisites: Basic Solid State Physics		
Objectives: ✓ The main objective of this course is to learn about optical and magnetic properties ofmaterials and their response to internal and external stimuli.		

Unit-1 **12 Hours**

Optical properties: Absorption, intraband and interband transition, Absorption spectra of materials, Luminescence, Fluorescence, phosphorescence, Colour centres, Basic ideas of Absorption and Fluorescence Spectroscopy. Lasers-principles, Induced absorption, Spontaneous Emission and stimulated Emission, Einstein A and B Coefficients, Ruby laser, Helium-Neon Laser and Semiconducting Laser.

Unit-2 **12 Hours**

Magnetism: Langevin Diamagnetism and Van Vleck Paramagnetism, Paramagnet: Derivations of Curie law, Pauli paramagnetic susceptibility, Ferromagnetism: Curie point and the exchange interaction, Curie-Weiss law, Ferrimagnetic order, Curie temperature and susceptibility of ferrimagnets, Antiferromagnetic order, susceptibility below the Neel temperature.

Unit-3

Dielectric and Ferroelectric Properties **12 Hours**

Maxwell equation and polarization, Macroscopic electric Field, local electric Field at an atom, Dielectric constant and polarizability, the classical theory of electronic, ionic and orientation polarization, Clausius Mossotti Relation, the Frequency dependence of polarization Structural phase transition, classification of ferroelectric crystal, Displacive Transitions: Soft optical phonon, Landau theory phase transition, second and first-order transition, Anti-ferroelectricity and Piezoelectricity

Unit-4 **12 Hours**

Novel Materials:

Metallic nanoclusters: Nanoscience and nanoclusters, liquid drop model, size and surface volume ratio. Graphene: Graphene lattice, tight binding approximation, Dirac Fermions

Characterization of materials: XRD, Bragg law, Laue conditions, Geometrical Structure factor and Atomic form factor, Basic principles of Electron Spin Resonance, NMR. Basic principles of Raman Effect in crystals and Mossbauer techniques

Text Books:

1. Introduction to Solid State Physics, C. Kittel, John Wiley and Sons, Inc. Singapore
2. Optical Properties of Solids, MarkFox, Oxford University Press
3. Physics of Condensed Matter- PrasantaK.Misra (Academic Press, 2010)

References:

4. Solid state Physics by Ashcroft and Mermin, Harcourt Asia PTE. Ltd. (A Harcourt Publishers International company)

Sub Code: PHY-E404B	**Nuclear Science-2 (Field Theory and Particle Physics)**	
Semester:4	**Credit:4**	**Elective**
Pre-requisites: Quantum Field Theory, Elementary Particle Physics and MathematicalPhysics.		
Course outcomes: ✓ To learn the field-theoretic techniques applicable to the interacting elementary particles and to be conversant with the current status of particle physics. ✓ To learn the fundamental concept of spontaneous breaking based on weak interaction and decay width calculation.		

Unit-1 **12 hours**

Field Theory:

Unequal space-time commutation and anti-commutation rules for field operators. Propagator functions and their integral representations, Vacuum expectation values, Feynmann propagators, Concept of T-Product and Normal Product, Feynman diagram rules in coordinate and momentum space, Wick's Theorem, Properties of scattering matrix, Brief idea of electron-photon scattering.

Unit-2 **12 hours**

Particle Physics:

Brief review of elementary particles and their interactions, SU (3) Quark Model, The Baryon and Meson State, Baryon-Meson coupling: The F and D terms, Gell-Mann-OKubo mass formula.The Heavy Quarks: Charm and Beyond, S.U. (6) Quark Model: wave-function forMesons and Baryons, Magnetic moment of Baryons.

Unit-3 **12 hours**

Weak Interaction: V-A form of weak interaction, Muon and Pion decay calculation, elementary notion of leptonic decays of strange particles, the Cabibbo angle, intermediate vector bosons, Elements of Neutral K-meson theory: Decay of Neutral K-mesons, regeneration of K- mesons, CP violation in neutral K decay.

Unit-4 **12 hours**

Spontaneous symmetry breaking, Higgs Mechanism, Brief idea of Salam-Weinberg Theory of Standard Model. Neutrino Physics: Neutrino Mass and Experimental limits, Neutrinoless Double-Beta decay, Neutrino oscillation, Solar neutrino puzzle, Magnetic moment of neutrino.

Textbooks and reading materials

1. Introduction to Elementary Particles by D. Griffiths, John Wiley & sons.
2. Relativistic quantum field theory by J.D. Bjorken and SD. Drell, Mc Graw-Hill Book Company.
3. An Introductory Course of Particle Physics, Palas.B.Pal. CRC Press.
4. Elementary particle physics by Gasiorwicz, Addison-Wesley Publishing Company
5. Elementary Particle Physics by G.Kallen, Addison-Wesley Publishing Company
6. Quarks and Leptons: F.Halzen and A.D.Martin, John Wiley.
7. A Modern introduction to particle physics: Fayyazuddin and Riazuddin, World Scientific, Singapore.

<table>
<tr><td>Sub Code: PHY-E405A</td><td colspan="2">CONDENSED MATTER &MATERIALS PHYSICS

(Laboratory work)</td></tr>
<tr><td>Semester:1</td><td>Credit:4</td><td>Elective Course</td></tr>
<tr><td colspan="3">Pre-requisites: Basic knowledge of Condensed Matter and Materials Physics</td></tr>
<tr><td colspan="3">Course outcomes:
✓ To design and analyze principles in Condensed Matter and Materials Physics.</td></tr>
</table>

1. Determination of energy gap of a given semiconductor by four probe method
2. Determination of the Hall constant of a sample and its identification
3. Determination of energy gap by p-n junction method
4. Study of the dispersion relation of an electric analog of the mono-atomic linear chain
5. Study of dispersion relation of an electric analog of diatomic linear chain

6. Determination of specific heat of a given sample using a thermocouple
7. Determination of dielectric constant of a given sample by lecher wire method
8. Determination of B-H curve of a given ferromagnet

Any other experiments that may be set up from time to time.

Sub Code: PHY-P405B	Nuclear Science (Laboratory work)	
Semester:1	**Credit:4**	**Elective Course**
Pre-requisites: Basic knowledge of Condensed and Material Physics		
Course outcomes: ✓ To design and analyze experiments in Nuclear Science		

1. Determination of half-life of unknown source
2. Determination of linear absorption coefficient
3. Verification of inverse square law
4. Experiment with gamma-ray spectrometer

i.Energy analysis of unknown gamma source
ii.Spectrum analysis of 60 Co and 137 Co
iii.The activity of Gamma emitter

5. High resolution of gamma-ray spectroscopy Energy resolution with Ge (Li)detector Photo pick efficiency for Ge(Li) detector

Any other experiments that may be set up from time to time

Sub Code: -VAC406	Cultural Heritage of Southy Odisha	
Semester:1	**Credit:4**	**VAC**
Pre-requisites:		
Course outcomes: ✓ The teaching imparted to PG students of Berhampur University on the various dimensions of the literary and cultural heritage of South Odisha will help them acquire a valuable understanding of the same.		

- ✓ They will be inspired adequately to take the positive learnt from the course and use them in future in their personal literary and cultural pursuits and their by promote the literature and culture of the odisha on a Global Scale

Unit I	Literary work of Kabi Samrat Upendra Bhanja
Unit II	Other Literatures of South Odisha
Unit III	Cultural Heritage of South Odisha
UNT IV	Folk and Tribal Traditions of South Odisha