NEHRU GRAM BHARATI

(DEEMED TO BE UNIVERSITY)

KOTWA-JAMUNIPUR, DUBAWAL, ALLAHABAD (U.P.)

Revised New Syllabus

(w.e.f. Sessoin-2017-18)

M.Sc. (PHYSICS)

(A Four Semester Course)

Based on

Choice Based Credit System (CBCS)

DEPARTMENT OF PHYSICS

Study & Evaluation Scheme based on Choice Based Credit System (CBCS)

M. Sc. –Physics

(A Four Semester Course)

[Effective from the session 2017-18]

SEMESTER-I											
Sr. No.	**Course Code**	**Title**	**Period**			**Evaluation Scheme**				**Subject Total**	**Credit**
						Internal Assessment			**ESE**		
			L	**T**	**P**	**CT**	**TA**	**Total**			
Four Compulsory Theory Papers											
1	PHY501	**Mathematical Physics**	2	1	0	10	10	20	80	100	3
2	PHY502	**Classical Mechanics**	2	1	0	10	10	20	80	100	3
3	PHY503	**Electromagnetic Theory**	2	1	0	10	10	20	80	100	3
4	PHY504	**Quantum Mechanics-I**	2	1	0	10	10	20	80	100	3
Lab Courses											
5	PHY531 PHY532	**Virtual Experiments** **Real Experiments**	0	0	12				100	100	6
Total			**8**	**4**	**12**	**40**	**40**	**80**	**420**	**500**	**18**
Total credits earned in Semester-I = 18											

Total Lectures in each theory paper: 48 Hrs or 48 Periods

L *– Lecture;* ***T*** *– Tutorial;* ***P*** *– Practical;* ***CT*** *- Cumulative Test*
TA *- Teacher's Assessment;* ***ESE*** *- End Semester Exam.*

SEMESTER-II											
Sr. No.	**Course Code**	**Title**	**Period**			**Evaluation Scheme**				**Subject Total**	**Credit**
						Internal Assessment			**ESE**		
			L	**T**	**P**	**CT**	**TA**	**Total**			
Four Compulsory Theory Papers											
1	PHY505	**Statistical Physics**	2	1	0	10	10	20	80	100	3
2	PHY506	**Solid State Electronics**	2	1	0	10	10	20	80	100	3
3	PHY507	**Atomic and Molecular Spectroscopy**	2	1	0	10	10	20	80	100	3
4	PHY508	**Quantum Mechanics-II**	2	1	0	10	10	20	80	100	3
Lab Courses											
5	PHY531 PHY532	**Virtual Experiments** **Real Experiments**	0	0	12				100	100	6
Total			**8**	**4**	**18**	**40**	**40**	**80**	**420**	**500**	**18**
Total credits earned in Semester-II = 18											

Total Lectures in each theory paper: 48 Hrs or 48 Periods

L *– Lecture;* ***T*** *– Tutorial;* ***P*** *– Practical;* ***CT*** *- Cumulative Test*
TA *- Teacher's Assessment;* ***ESE*** *- End Semester Exam.*

SEMESTER-III											
Sr. No.	**Course Code**	**Title**	**Period**			**Evaluation Scheme**				**Subject Total**	**Credit**
						Internal Assessment			**ESE**		
			L	**T**	**P**	**CT**	**TA**	**Total**			
Two Compulsory Theory Papers											
1	PHY601	**Condensed Matter Physics**	2	1	0	10	10	20	80	100	3

SEMESTER-IV										
Sr. No.	**Course Code**	**Title**	**Periods**			**Evaluation Scheme**				**Subject Total**	**Credit**
						Internal Assessment			**ESE**		
			L	**T**	**P**	**CT**	**TA**	**Total**			
Specialization-1: Nanoscience & Nanotechnology											
3(a)	PHY651	**Introduction to Nanoscale Science and Technology**	2	1	0	10	10	20	80	100	3
4(a)	PHY652	**Synthesis and Characterization of Nanomaterials**	2	1	0	10	10	20	80	100	3
Specialization-2: Laser and Spectroscopy											
3(b)	PHY653	**Laser Spectroscopy**	2	1	0	10	10	20	80	100	3
4(b)	PHY654	**Electronic Spectra of Diatomic Molecule**	2	1	0	10	10	20	80	100	3
One Lab Course from the Chosen Elective Specialization											
5(a)	PHY631/ PHY632	**Nanoscience & Nanotechnology**	0	0	12				100	100	6
5(	PHY631/ PHY632	**Laser and Spectroscopy**	0	0	12				100	100	6
Total			**8**	**4**	**12**	**40**	**40**	**80**	**420**	**500**	**18**
Total credits earned in Semester-III = 18											

Total Lectures in each theory paper: 48 Hrs or 48 Periods

L *– Lecture;* ***T*** *– Tutorial;* ***P*** *– Practical;* ***CT*** *- Cumulative Test*
TA *- Teacher's Assessment;* ***ESE*** *- End Semester Exam.*

One Compulsory Theory Paper											
1	PHY603	**Experimental Techniques & Control Systems**	2	1	0	10	10	20	80	100	3
One Elective Theory Paper from the following Four Electives											
ELECTIVE-1											
2(a)	PHY663	**Nanobiotechnology**	2	1	0	10	10	20	80	100	3
ELECTIVE-2											
2(b)	PHY664	**Fundamentals of Laser and its Applications**	2	1	0	10	10	20	80	100	3
ELECTIVE-3											
2(c)	PHY665	**Programming for Numerical Methods**	2	1	0	10	10	20	80	100	3
ELECTIVE-4											
2(d)	PHY666	**Group Theory**	2	1	0	10	10	20	80	100	3
Two Elective Theory Papers from any of the following Two Specializations											
Specialization-1: Nanoscience & Nanotechnology											
3(a)	PHY667	**Micro and Nanofabrication**	2	1	0	10	10	20	80	100	3
4(a)	PHY668	**Application of Nanotechnology**	2	1	0	10	10	20	80	100	3
Specialization-2: Laser and Spectroscopy											
3(b)	PHY669	**Advanced Atomic Spectroscopy**	2	1	0	10	10	20	80	100	3
4(b)	PHY670	**IR & Raman Spectra of Polyatomic Molecules**	2	1	0	10	10	20	80	100	3
One Thesis/Dissertation from the Chosen Elective Specialization											
5	PHY633	**Thesis/Dissertation**	0	0	12				100	100	6
Total			**8**	**4**	**12**	**40**	**40**	**80**	**420**	**500**	**18**
Total credits earned in Semester-IV = 18											

L *– Lecture;* ***T*** *– Tutorial;* ***P*** *– Practical;* ***CT*** *- Cumulative Test* ***TA*** *- Teacher's Assessment;* ***ESE*** *- End Semester Exam*

*** (Thesis/Dissertation will be assigned at the beginning of Semester III)*

Note: In the Semester system described above total credits earned is 4×18=72.

Paper Setting pattern for End Semester Examination

1. **Each question paper consists of nine questions in all and divided into three sections-Section-A, Section-B & Section-C.**
2. **First question of Sec-A will be compulsory of objective/ Short Answer/Fill in the blanks of ten questions as UGC-CSIR/NET Standard. Total Marks: 20 (2 marks of each).**
3. **Section B has Five questions from units I, II, & III. Each question may be divided into more than one part. Attempt any three from this section. Total Marks: 36 (12 marks each)**
4. **Section C has Three questions from units IV & V. Each question may be divided into more than one part. Attempt any two from this section. Total Marks: 24 (12 mark each)**

Semester-I

Paper-I: MATHEMATICAL PHYSICS **PHY501**

Unit-I: Ordinary Differential Equations and Special Functions
Linear ordinary differential equations of first & second order, Special functions (Hermite, Bessel, Laguerre and Legendre functions). Partial differential equations (Laplace, wave and heat equations in two and three dimensions).

Unit-II: Complex Analysis and Integral Transforms
Analytic functions, Cauchy-Riemann conditions, classification of singularities, Cauchy's theorem, Taylor & Laurent series; poles, residues and evaluation of integrals. Fourier series, Fourier and Laplace transforms, Dirac Delta function and Green's function.

Unit-III: Vectors and Matrices
Vector algebra and vector calculus. Matrix spaces, linear operators, eigenvectors and eigenvalues, matrix diagonalization, special matrices.

Unit-IV: Tensor Analysis
General coordinate transformation; contravariant, covariant and mixed tensors; metric tensor; raising and lowering of indices; contraction of indices.

Unit-V: Lorentz Group
Lorentz group; Homogeneous Lorentz transformation, the group property, proper, improper and orthocrhronus transformations; Inhomogeneous (Poincare) Lorentz transformation, Psedo-tensors.

Text & Reference Books:

1. *Mathematical Physics by P. K. Chattopadhyay (New Age International Publishers Ltd.)*
2. *Mathematical Physics by B.S. Rajpoot (Pragati Prakashan).*
3. *Advanced Engineering Mathematics, 19/e by H.K. Dass (S. Chand)*
4. *Mathematical Methods for Physicists, 7/e by G.B. Arfken, H. Weber, F. Harris (Elesvier Publisher).*
5. *Mathematics for Physicists by P. Dennery and A. Krzywicki (Dover Publications).*
6. *Matrices and Tensors in Physics, 3/e by A.W. Joshi (New Age International).*
7. *Complex Variables and Applications, 8/e by J.W. Brown and R.V. Churchill (McGraw-Hill Higher Education).*
8. *Schaum's Outline of Complex Variables 2/e by J. Schiller, M. R. Spiegel, Seymour Lipschutz (Tata McGraw - Hill Education).*
9. *Schaum's Outline of Vector Analysis, 2/e by M.R. Spiegel and S. Lipschutz (Tata McGraw - Hill Education).*
10. *Group Theory in Physics by Wu Ki Tung (World Scientific).*

Paper-II: CLASSICAL MECHANICS **PHY502**

Unit-I: Lagrangian Dynamics
Generalized coordinates and constraints, D'Alembert Principle and Lagrange' equations, Lagrange's equations of motion, conservation laws, generalized momenta.

Unit-II: Variational principles & Hamilton formalisms
Calculus of variations, Hamilton's principle Legendre transformations, Hamilton's equations (canonical) of motion, cyclic coordinates, conservations theorem, Noether's Theorem.

Unit-III: Canonical Transformations and Hamilton-Jacobi Theory
Canonical transformations, generating functions, Poisson brackets, Lagrange brackets, infinitesimal contact transformations, Jacobi identity, Liouville's theorem, Hamilton-Jacobi theory; Hamilton-Jacobi equation, action-angle variables.

Unit-IV: Small Oscillations and Normal Modes
Small oscillations about a stable equilibrium, Linearization of equations of motion, free vibrations and normal coordinates, coupled oscillations and normal mode analysis, forced vibrations and effect of dissipative forces.

Unit-V: Special Theory of Relativity
Four Dimensional Formulations; Space-time metric of special relativity, Minkowiski space diagram and Lorentz transformations, light cone and principle of causality; invariance of Minkowski metric under Lorentz transformations, The Lagrangian formulation of relativistic mechanics, covariant Lagrangian formulations, Introduction to general theory of relativity.

Text & Reference Books:

1. *Classical Mechanics by N.C. Rana and P.S. Joag (McGraw Hill Education, 1991).*
2. *Classical Mechanics, 2/e by J.C. Upadhyaya (Himalaya Publishing House, 2011).*
3. *Classical Mechanics, 3/e by H. Goldstein, C.P. Poole and J. Safko (Pearson, 2011)*
4. *Mechanics, 3/e by L. D. Landau, E. M. Lifshitz, E. M. Lifshitz Joint (Butterworth-Heinemann, 1976).*
5. *Introduction to Dynamics by I.C. Percival and D. Richards (Cambridge University Press, 1982).*
6. *Classical Dynamics: A Contemporary Approach by J.V. Jose and E.J. Saletan (Cambridge University Press, 1998).*
7. *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies by E.T. Whittaker (Cambridge University Press, 1988).*

Paper-III: ELECTROMAGNETIC THEORY **PHY503**

Unit-I: Material Equations, Maxwell's Equations and Gauges

Microscopic and Macroscopic fields, Macroscopic Maxwell's equations, Field D and H, Dielectric tensor, Principal dielectric axes. Displacement current, Maxwell's equations, vector and scalar potentials, gauge transformation, Coulomb and Lorentz gauges, electromagnetic energy and momentum, conservation laws, inhomogeneous wave equation and Green's function solution.

Unit-II: Electromagnetic Waves in crystals and optically active media

Structure of monochromatic plane wave in anistropic medium, Fresnel's formulae for propagation of light in crystals, duality, geometrical constructions, ellipsoid of wave normals and ray ellipsoid, propogation of light in uniaxial crystals.

Unit-III: Guided Electromagnetic Waves

Electromagnetic wave propagation metallic wave guides boundary conditions at metallic surfaces, transmission lines, propagation modes in wave guides, mode of vibration in a rectangular wave-guide, resonant modes in cavities and quality factor.

Unit-IV: Covariant Formulation of Electrodynamics-I

Four-vectors relevant to electrodynamics, Charge-current density four-vectorGauge invariance; Electromagnetic potential four-vector; Electromagnetic field tensor; Lorentz transformation of electric and magnetic fields; Invariants of the electromagnetic field.

Unit-V: Covariant Formulation of Electrodynamics-II

Electromagnetic field of a charge moving with constant velocity, Covariant form of Lorentz force law; Dynamics of charged particles in static and uniform electric fields.

Text and Reference Books:

1. *Electromagnetics, 2/e by B. B. Laud (New Age International, 1987)*
2. *Electromagnetic Theory and Radiation Systems, 2/e by E.C. Jordan & K.G. Balman (PHI Learning, 1968)*
3. *Introduction to Electrodynamics, 3/e by D.J. Griffiths (PHI Learning, 1999)*
4. *Classical Electrodynamics, 3/e by J.D. Jackson (John Wiely & Sons, 2004)*
5. *Principles of Optics, 7/e by M. Born & E. Wolf (Cambridge University Press, 1999)*
6. *An Introduction to Microwave Theory by H.A. Atwater (Krieger Pub Co., 1981).*
7. *Electronic and Radio Engineering, 4/e by F. E. Terman (McGraw-Hill, 1955)*
8. *Foundations of Electromagnetic Theory, 4/e by J.R. Reitz, F.J. Milford and R.W. Christy (Addison-Wesley, 2008).*
9. *Classical Electricity and Magnetism, 2/e by W.K.H. Panofsky and M. Phillips (Dover Publications, 2005).*

Paper-IV: QUANTUM MECHANICS **PHY504**

Unit-I: Structure of Quantum Mechanics
Dirac's Bra & Ket Notations, Hilbert Space, Vector Representations of States, Orthonomality and Completeness of States, Relation between Ket and Wave-functions, Wave-functions in Coordinate and Momentum Representations, Matrix Theory of Harmonic Oscillator, Uncertainty Relations.

Unit-II: Angular Momentum-I
Rotation operators, Orbital Angular Momentum, angular momentum algebra, eigen values of J^2 and J_z, spinors and Pauli matrices, addition of angular momenta.

Unit-III: Angular Momentum-II
Clebsch-Gordan Coefficients, Explicit Addition of Angular Momentum ½ with Angular Momenta ½ and 1, Spherical Harmonics in Central Field Problems, Spin-Orbit Coupling, Fine-Structure.

Unit-IV: Quantum Dynamics and Operators
Interaction pictures, Schrödinger, Heisenberg and Dirac Representations, Equation of motion of operators in Schrödinger and Heisenberg representations, Density operator, Projection operator, Reflection operator, positions representation.

Unit-V: Second Quantization of Non-Relativistic Fields
Non-Covariant Derivation of Lagrangian Equations for fields, Canonically Conjugate Momentum Density for Schrodinger Field, Quantum Conditions based on Commutation Relations and Second Quantization, Annihilation and Creation Operators, Second Quantization based on Anti-Commutation Relations, Simple Problems on Algebra of Annihilation and Creation Operators.

Text & References Books:

1. *Quantum Mechanics & Field Theory by B. K. Agarwal (Lokbharti Prakashan,).*
2. *Quantum Mechanics by A. Ghatak and S. Loknathan (Macmillan, 1999).*
3. *Modern Quantum Mechanics, 2/e by J.J. Sakurai (Pearson,2010)*
4. *Introduction to Quantum Mechanics, 2/e by D.J. Griffits (Pearson, 2005).*
5. *Quantum Mechanics: Concepts and Applications, 2/e by N. Zettili (John Wiley & Sons, 2001).*
6. *Quantum Mechanics, 3/e by L.I. Schiff (Tata McGraw - Hill Education, 1949)*
7. *Quantum Mechanics, 3/e by E. Merzbacher (John Wiely & Sons,1997)*
8. *Quantum Mechanics, 2/e by K. Gottfried, T.M. Yan, Tung-Mow Yan (Springer,2008)*
9. *Feynman Lectures on Physics (Volume 3) by R.P. Feynman (Narosa, 2008)*

Semester-II

Paper-I: STATISTICAL MECHANICS **PHY505**

Unit-I: Review of Statistical Mechanics
Concept of Phase Space, Basic Postulates of Statistical Mechanics, Ensembles: Micro-canonical, Canonical, Grand canonical, and isobaric, connection to thermodynamics, fluctuations, applications of various ensembles, a review of Gibbs ensembles, Classical and Quantum Statistics, Distribution Functions.

Unit-II: Classical Statistics
Maxwell-Boltzmann Statistics, Partition function for Perfect Gas and ensemble of Harmonic Oscillators, Partition Function for Gases containing Monoatomic, Diatomic and Polyatomic Molecules. Specific Heat Capacity of Gases and Solids, Saha's Ionization formula, Grand partition function, Grand potential.

Unit-III: Quantum Statistics
Fermi-Dirac (FD) and Bose-Einstein (BE) statistics, FD and BE distribution in Grand Canonical ensemble, Ideal Bose gas, Debye theory of specific heat, black-body radiation, Bose- Einstein condensation, Degenerate Bose Gas, Momentum Condensation, Liquid He II, Two fluid theory, Sperfluidity, Degenerate FD Gas, Conduction Electrons in a Metal.

Unit-IV: Fluctuations and Noise-I
Fluctuations, One dimensional Random walk, Gaussian Distribution, Fluctuation in energy in canonical ensemble and the concentration in Grand Canonical ensemble.

Unit-V: Fluctuations and Noise-II
Random processes, Markoff process, Langevin Equation, Correlation functions, Fluctuation-Dissipation Theorem, Weiner-Khintchine theorem, Nyquist theorem, Conditional probability, Fokker Plank Equation, Brownian motion, Onsager relations.

Text & Reference Books:

1. *Statistical Mechanics, 3/e by B. K. Agarwal & M. Eisner (New Age International (p) Limited, 2013).*
2. *Fundamentals of Statistical Mechanics, 2/e by B. B. Laud (New Age International Publishers Ltd.-New Delhi, 2012).*
3. *Elementary Statistical Physics by C. Kittel (Dover Publications, 2008).*
4. *Statistical Mechanics, 3/e by R.K. Pathria & P.D. Beale (Elsevier, 2011).*
5. *Statistical Physics by C. Hermann (Springer, 2005).*
6. *Berkeley Physics Course, Vol 5: Statistical Physics by F. Rief (McGraw-Hill, 2008).*
7. *Statistical Physics by L.D. Landau and E.M. Lifshitz (Pergamon Press, Oxford).*

Paper-II: SOLID STATE ELECTRONICS **PHY506**

Unit-I: P-N Junction Diode

Rectifier with LC Filter, Electronic regulator. Bipolar Junction Transistors: h-parameters, inter conversion in different configurations, low frequency transistor amplifier, thermal stability and bias stabilization.

Unit-II: Field Effect Transistors

Small signal model and dynamic parameters, CS and CD amplifiers. Multistage Amplifiers: BJT at high frequencies, frequency response of gain and phase shift, frequency response of RC coupled amplifier.

Unit-III: Feedback Amplifiers and Oscillators

Classification, Different Negative Feedback Amplifiers, Stability and Nyquist Criteria Sinusoidal Oscillators, Phase Shift and Wien's Bridge Oscillators, Crystal Oscillators, Astable Multivibrator.

Unit-IV: Power and RF Amplifier

Large Signal Amplifier and Distortions, Transformer Coupled Audio Power Amplifiers, Push-Pull amplifier, Single and Double Tuned Amplifiers.

Unit-V: Modulation and De-Modulation:

Frequency Spectrum and Power in Amplitude Modulation (AM) wave, Amplitude Modulating Circuits, Frequency and Phase Modulations, Frequency Modulator, Frequency Changing and Tracking; Automatic Gain Control (AGC), Automatic Frequency Control (AFC), FM Detection, Amplitude Limiter, Phase Discriminator, Ratio Detector.

Text & Reference Books:

1. *Hand Book of Electronics, 38/e by S. L. Gupta & V. Kumar (Pragati Prakashan).*
2. *Electronic Device & Circuits, 3/e by J. Milliman & C.C. Halkias (McGraw-Hill).*
3. *Modern Digital Electronics 4/e by R.P. Jain (Tata McGraw - Hill Education).*
4. *Electronic Device & Circuits by A. Mottershead (PHI Learning).*
5. *Principles of Communication Systems, 2/e by H. Taub & D. Schilling (McGraw-Hill).*
6. *Electronic Fundamentals and Applications, 5/e by J.D. Ryder (PHI Learning).*
7. *Digital Integrated Electronics by H. Taub & D. Schilling (McGraw-Hill).*
8. *Digital Principles and Applications by A.P. Malvino & D.P. Leach (McGraw-Hill).*
9. *Digital Logic and Computer Design by M. Morris Mano (PHI Learning).*
10. *Microelectronics by J. Millman and A. Grabel (McGraw-Hill).*

Paper-III: ATOMIC AND MOLECULAR SPECTROSCOPY PHY507

Unit-I: Atomic Spectroscopy-I

Review of He atom, ground state and first excited state, Quantum states of an electron in an atom, Spectrum of Hydrogen and Helium atom, fine structure, Spectra of Alkali atoms; energy level diagrams. Sharp, Principal, Diffuse and fundamental series,

Unit-II: Atomic Spectroscopy-II

Width of spectral lines, Spectroscopic terms; LS & JJ couplings, Hyperfine structure, Zeeman, Paschen Back & Stark effect, X-ray spectroscopy(Characteristic and continuous).

Unit-III: Microwave Spectroscopy of Diatomic Molecules

Rotational Spectra (Rigid rotator and Non-Rigid Rotator Models), Isotopic Effect in Rotational Spectra, Symmetric and Asymmetric Top Molecules, Microwave Spectrometer), Chemical Analysis by Microwave Spectroscopy, The Microwave Oven.

Unit-IV: Infra-red Spectroscopy of Diatomic Molecules

Vibrational Spectra (Harmonic and Anharmonic models), Selection rules, Term Schemes, Molecular Symmetric Top, Vibrating Rotator, Isotopic Shift, Infra-red (IR) Spectrophotometer, Fourier Transform Infra-red (FTIR) Spectroscopy and Applications.

Unit-V: Raman and Electronic Spectroscopy of Diatomic Molecules

Raman Spectra (Quantum Mechanical and Classical Approach), Structure Determination from Raman and IR Spectroscopy, Techniques and Instrumentation (Raman Spectrometer), Near Infra-red FT-Raman Spectroscopy. Electronic Spectra-Vibrational Structure of Band System, Fine Structure of the Band Systems, Intensity Distribution in Band Systems: Frank Condon principle, Techniques and Instrumentation (Photoelectron Spectrometer).

Text & Reference Books:

1. *Atomic and Molecular Spectra by Raj Kumar (Kedar Nath Ram Nath).*
2. *Molecular Structure and Spectroscopy by G. Aruldhas (PHI Learning).*
3. *Introduction to Atomic Spectra by H. E. White (McGraw-Hill).*
4. *Molecular Spectra and Molecular Structure, Vol I: Spectra of Diatomic Molecules by G. Herzberg (Krieger Publishing Company).*
5. *Fundamental of Molecular Spectroscopy,4/e by C. N. Banwell (McGraw-Hill)*
6. *Atoms and Molecules: An Introduction for Students of Physical Chemistry by M. Karplus and R.N. Porter (Benjamin–Cummings Publishing Company).*

Paper-IV: QUANTUM MECHANICS-II **PHY508**

Unit-I: Approximate Methods-I

- **(i)** **Time-Independent Perturbation Theory:** Non degenerate Perturbation Theory, Degenerate Perturbation Theory, Fine Structure of Hydrogen.
- **(ii)** **Variational Method**: Basic Principle, Hydrogen Atoms, He-Atoms.
- **(iii)** **WKB Method**: Applications, Correction formula.

Unit-II: Approximate Methods-II

- **(iv)** **Time-Dependent Perturbation Theory**, Constant and Harmonic Perturbation, Transition probabilities, Fermi's Golden Rule.
- **(v)** **Semi-Classical Theory of Radiation,** Einstein A and B Coefficients, Selection Rules.

Unit-III: Scattering

- **(vi)** Scattering, Method of Partial Waves, Phase-Shifts, Born Approximation, Simple Applications.

Unit-IV: Relativistic Quantum Mechanics

Klein Gordon Equation and Free Particle Solution,Dirac Equation, Dirac Matrices, Covariance of Dirac Equation & Bilinear Covariants, Solution for a Free Particle, Negative Energy states and Hole Theory, Spin, Position Operator.

Unit-V: Lagrangian and Hamiltonian Formalisms for Relativistic Quantum Mechanics

Derivation of Lagrangian and Hamiltonian equations. Symmetry transformations and conservations laws, energy-momentum, Angular Momentum and Spin tensors, Current-Density four vector.

Text & Reference Books:

1. *Quantum Mechanics & Field Theory by B. K. Agarwal (Lokbharti Prakashan).*
2. *Quantum Mechanics by A. Ghatak and S. Loknathan (Macmillan).*
3. *Introduction to Quantum Mechanics, 2/e by D.J. Griffits (Pearson).*
4. *Quantum Mechanics: Concepts and Applications, 2/e by N. Zettili (John Wiley & Sons).*
5. *Mordern Quantum Mechanics, 2/e by J. J. Sakurai (Pearson Education India).*
6. *Quantum Mechanics, 3/e by L.I. Schiff (Tata McGraw - Hill Education)*
7. *An Introduction to Relativistic Quantum Mechanics & Field Theory by S.S. Schweber (Dover Publications).*
8. *Relativistic Quantum Mechanics, 1/e by S.D. Drell and J.D. Bjorken (Tata McGraw - Hill Education).*
9. *Theory of Quantized Field by P. Roman*
10. *Quantum Mechanics by E. Merzbacher(John Wiely & Sons)*
11. *Quantum Mechanics, 2/e by K. Gottfried, T.M. Yan, Tung-Mow Yan (Springer)*
12. *Feynman Lectures on Physics (Volume 3) by R.P. Feynman (Narosa)*

Semester-I and II Laboratory course

PHY531: VIRTUAL LABORATORY EXPERIMENTS

1. Franck-Hertz Experiment

To experimentally demonstrate the concept of quantization of energy levels according to Bohr's model of atom.

2. Seebeck Effect

To verify the relation between thermo emf of a thermocouple and temperature difference between two hot junctions.

3. Photo-Electric Effect

To understand the phenomenon photoelectric effect as a whole.

4. Quincke's Method

To determine the volume magnetic susceptivility of manganese sulphate solution at different concentrations.

5. Comparator

To study the comparator and simulate it.

6. Fluorescence

Determination of florescence quantum yield of a fluorophore.

7. PH-Effect

Demonstration of pH effect on fluorescence excitation and emission spectra of a fluorophore.

PHY532: REAL LABORATORY EXPERIMENTS

1. Forbidden Energy Band
2. Botzmann constant
3. Capacity and Permittivity
4. Curie Temperature
5. Modulation and Demodulations
6. Energy Band Gap of Si & Ge Diodes
7. Double Stage Amplifier
8. Design of CE Amplifier
9. Design of Regulated Power Supply

Note: Addition and deletion in the list of experiments may be made from time to time by the department

Semester-III

Paper-I: CONDENSED MATTER PHYSICS **PHY601**

Unit-I: Electron band theory: One electron band theories. Plane wave like and localized wave functions. Nearly free electron approximation. Elementary discussion of orthogonalized Plane Wave (OPW) and Pseudo potential methods. Variation of Fermi energy in extrinsic semiconductors. de-Hass-van Alphen effect experiment to investigate Fermi surface.

Unit-II: Superconductivity: Meissner effect, isotope effect, type I and II superconductors. Cooper pairs. Elementary ideas of BCS theory. Approximate estimate of transition temperature, superconducting energy gap , Measurement of energy gap by infrared absorption and electron tunneling methods, Elementary ideas about Josephoson effect and high Tc superconductors.

Unit-III: Ionic lattice in presence of infrared field, dielectric constant, L.S.T. relation, LO and TO modes. Ordered phases of matter, translational and orientational order, Quasicrystals, conducting polymers

Unit-IV: Lattice defects: Frenkel and Schotty defects, colour centres, number of defects (vacancies) in equilibrium, Dislocations, edge and screw Burgers vector..

Unit-V: Magnetic properties: Diamagnetism, Langevin diamagnetic equation, Quantum theory of paramagnetism rare earth ions and iron group ions. Ferromagnetism, Curie temperature, Heisenberg model, Temperature dependence of saturated magnetization.

Text & Reference Books:

1. *S. O. Pillai, Solid State Physics (New Age International (p) Limited, 2013).*
2. *Solid State Physics by C. Kittel (Willey, 2008).*
3. *Solid State Physics by A. J. Dekker (Macmillan).*
4. *Principles of Condensed Matter Physics by Chaikin and lubensky*
5. *Solid State Physics by M A Wahab*
6. *Introduction to Solids by Azaroff*
7. *Elementary Solid State physics by Omar*
8. *Solid State Physics by Aschroft & Mermin*

Paper-II: NUCLEAR PHYSICS **PHY602**

Unit-I: Two body problem: Deuteron, n-n scattering, n-p scattering, p-p scattering, charge independence and charge symmetry of nuclear forces.

Unit-II: Nuclear Models: Shell Model, Extreme Single particle picture and angular momentum, magnetic moment, quadrupole moment of nuclei, Nuclear Isomerism, Collective model (qualitative discussion).

Unit-III: Nuclear Reactions: Compound Nucleus, Breit Wigner Formula, Direct Interaction, Heavy Ion Reactions, Relativistic Kinematics.

Unit-IV: Nuclear Decays: Alpha, beta and gamma decay.

Unit-V: Elementary particles: Fundamental types of Interactions, General Classifications of Elementary Particles, Isospin, Strangeness, Conservation Laws, Symmetries (C, CP, CPT), SU(3) and quark model.

Text & Reference Books:

1. *Nuclear Physics by S.N. Ghoshal, S. Chand & Company Ltd,2004*
2. *Introducing Nuclear Physics by K. S. Krane (Wiley India., 2008) .*
3. *Nuclear Physics - Theory & Experiments by R.R. Roy & B.P.Nigarn (New Age international,2005)*
4. *Nuclear & Particle Physics: An Introduction by B. Martin (Willey,2006)*
5. *Concept of Nuclear Physics by B. L. Cohen (McGraw-Hill,2003)*

Semester-III

Specialization-I: Nanoscience & Nanotechnology

Paper-III: INTRODUCTION TO NANOSCALE SCIENCE AND TECHNOLOGY
PHY651

Unit-I: Generic Methodologies for Nanotechnology
Introduction and classification - What is nanotechnology?, Milestone and History of nanotechnology - Classification of nanostructures - Nanoscale architecture; Summary of the electronic properties of atoms and solids - The isolated atom - Bonding between atoms - Giant molecular solids - The free electron model and energy bands - Crystalline solids - Periodicity of crystal lattices - Electronic conduction; Effects of the nanometre length scale - Changes to the system total energy - Changes to the system structure - How nanoscale dimensions affect properties.

Unit-II: Carbon Nanostructures
Introduction; carbon molecules – nature of the carbon bond – new carbon structures; cabon clusters – small carbon clusters discovery of C60 – structure of C60 and its crystal – alkali doped C60 – superconductivity in C60 – large and smaller fullerenes – other buckyballs; carbon nanotubes – fabrication – structure – electrical properties – vibrational properties – mechanical properties; applications of carbon nanotubes – field emission and shielding – computers – fuel cells – chemical sensors – catalysis – mechanical reinforcement.

Unit-III: Inorganic Nanostructures
Metal Nanostructures (Au, Ag, Cu, Al)-Surface Plasmon Resonance, Properties and Application of metal Nanostructures. Overview of relevant semiconductor physics - Quantum confinement in semiconductor nanostructures - The electronic density of states - Fabrication techniques - Physical processes in semiconductor nanostructures (e.g, ZnO etc) - The characterization of semiconductor nanostructures - Applications of semiconductor nanostructures.

Unit-IV: Nanostructured Molecular Materials
Introduction; Building blocks - Principles of self-assembly - Self-assembly methods to prepare and pattern nanoparticles - Templated nanostructures - Liquid crystal mesophases - Macromolecules at interfaces - The principles of interface science - The analysis of wet interfaces - Modifying interfaces - Making thin organic films - Surface effects on phase separation - Nanopatterning surfaces by self-assembly - Practical nanoscale devices exploiting macromolecules at interfaces .

Unit-V: Evolving Interfaces of Nano
Nanobiology - Introduction - Bio-inspired nanomaterials - Interaction Between Biomolecules and Nanoparticle Surfaces - Different Types of Inorganic Materials Used for the Synthesis of Hybrid Nano-bio Assemblies - Applications of Nano in Biology - Nanoprobes for Analytical Applications - Current Status of Nanobiotechnology - Future Perspectives of Nanobiology; Nanosensors - Introduction - What is a Sensor? - Nanosensors - Order from Chaos - Characterization - Perception - Nanosensors Based on Quantum Size Effects - Electrochemical Sensors - Sensors Based on Physical Properties - Nanobiosensors - Smart

Dust; Nanomedicines - Introduction - Approach to Developing Nanomedicines - Various Kinds of Nanosystems in Use - Protocols for Nanodrug Administration - Nanotechnology in Diagnostic Applications - Materials for Use in Diagnostic and Therapeutic Applications - Future Directions.

Text & Reference Books:

1. *Nanoscale Science and Technology, Robert W. Kelsall, Ian W. Hamley and Mark Geoghegan, John Wiley & Sons, Ltd., UK, 2005.*
2. *Introduction to Nanotechnology, Charles P. Poole Jr and Frank J. Owens, Wiley Interscience, 2003.*
3. *Bio-Inspired Nanomaterials and Nanotechnology, Edited by Yong Zhou, Nova Publishers.*
4. *Nano:The Essentials: Understanding Nanoscience and Nanotecnology, T.Pradeep, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2008.*

Paper-IV: SYNTHESIS AND CHARACTERIZATION OF NANOMATERIALS

PHY652

Unit-I: Physical and Chemical Methods

Ball Milling – Electrodeposition - Spray Pyrolysis - Flame Pyrolysis - Inert Gas Condensation Technique (IGCT) – Thermal evaporation – Pulse Laser Ablation in Liquid Media (Metal nanoparticles-Au/Ag/Cu/Al)-Pulsed Laser Deposition (PLD) – DC/RF Magnetron Sputtering - Molecular Beam Epitaxy (MBE), Sol-Gel Process — Self assembly – Metal Nanocrystals by Reduction - Solvothermal Synthesis - Photochemical Synthesis - Sonochemical Routes – Reverse Micelles and Micro emulsions - Combustion Method – Template Process - Chemical Vapor Deposition (CVD) – Metal Oxide Chemical Vapor Deposition (MOCVD)

Unit -II: Lithographic Methods

Introduction – Lithography – Photolithography - Phase-shifting photolithography - Electron beam lithography - X-ray lithography - Focused ion beam (FIB) lithography - Neutral atomic beam lithography - Nanomanipulation and Nanolithography - Soft Lithography - Assembly of Nanoparticles and Nanowires Other Methods for Microfabrication.

Unit -III: Biological Synthesis and Nanocomposites

Introduction - Natural Nanocomposite Materials - Biologically Synthesized Nanoparticles, Nanostructures and Synthetic Nanocomposites - Protein-Based Nanostructure Formation - DNA-Templated Nanostructure Formation - Protein Assembly - Biologically Inspired Nanocomposites - Lyotropic Liquid-Crystal Templating - Liquid-Crystal Templating of Thin Films - Block-Copolymer Templating - Colloidal Templating. Ceramic/Metal Nanocomposites - Metal Matrix Nanocomposites - Nanocomposites for Hard Coatings – Polymer based nanocomposites – nanoscale fillers – processing of polymer nanocomposites – Properties of polymer nanocomposites.

Unit -IV: Characterization Methods- I

X-ray diffraction (XRD) - Debye-Scherer formula – dislocation density – micro strain – Synchrotron Radiation – Principle and Applications –Raman Spectroscopy and its Applications – Dynamic Light Scattering (DLS). Electron microscopes: scanning electron microscope (SEM) – transmission electron microscope (TEM); atomic force microscope (AFM) – scanning tunneling microscope (STM) - XPS – Working Principle, Instrumentation and Applications.

Unit -V: Characterization Methods - II

Impedance Analysis - Micro hardness - nanoindentation – vibrating sample magnetometer – Nuclear Magnetic Resonance (NMR). Differential scanning calorimeter (DSC) – Thermogravimetric/Diffferential Thermal Analyzer (TG/DTA) – UV – Visible Spectrophotometer - FTIR – Principle and Applications – Photoluminescence (PL) Spectroscopy.

Text & Reference Books:

1. *Recent Advances in the Liquid-phase syntheses if inorganic nanoparticles, Brain L.Cushing, Vladimir L.Kolesnichenko, Charles J. O'Connor, Chem Rev. 104 (2004) 3893-3946.*

2. *Nanocrystals: Synthesis, Properties and Applications, C. N. R. Rao, P. J. Thomas and G. U. Kulkarni, Springer (2007).*
3. *Nanotechnology - Enabled Sensors, Kourosh Kalantar-zadeh and Benjamin Fry, Springer (2008).*
4. *Nanostructures & Nanomaterials: Synthesis, Properties & Applications, Guozhong Gao, Imperial College Press (2004).*
5. *Nanochemistry: A Chemical Approach to Nanomaterials – Royal Society of Chemistry, Cambridge, UK (2005).*
6. *Nanocomposite science and technology, Pulickel M.Ajayan, Linda S.Schadler, Paul V.Braun, Wiley-VCH Verlag, Weiheim (2003).*
7. *Encyclopedia of Materials Characterization, C. Richard Brundle, Charles A. Evans Jr., Shaun Wilson, Butterworth-Heinemann Publishers (1992).*
8. *Handbook of Microscopy for Nanotechnology, Ed. By Nan Yao and Zhong Lin Wang, Kluwer Academic Press (2005).*
9. *Nanochemistry, G. B. Sergeev, Elsevier (2006).*
10. *Nanotechnology: Basic Science and Emerging Technologies – Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, Overseas Press (2005).*
11. *Handbook of Analytical Techniques, Edited By Helmut Günzler and Alex Williams, Wiley VCH, 2002.*

Specialization-II: Laser and Spectroscopy

Paper – III: LASER SPECTROSCOPY **PHY653**

Unit-I: Light Sources (Arc, Spark, Discharge, Beam Foil etc.), Synchrotron, Laser, Thermal and Direct Photo Detectors, Optical Multichannel Analyzer, Charged Coupled Devices (CCD), Intensified Charged Coupled Devices (ICCD).

Unit-II: Fixed-frequency and Tunable lasers, YAG, Argon Ion, Excimer, Dye, Semiconductor Lasers.

Unit-III: Laser Photoacoustic Spectroscopy, Laser Induced Fluorescence (LIF), Laser Induced Breakdown Spectroscopy (LIBS), Laser Optogalvanic Spectroscopy.

Unit-IV: Laser Raman Spectroscopy (CARS, SRS, SERS), Time Resolved Spectroscopy.

Unit-V: Fourier Transform Spectroscopy, Laser Isotope Separation, Medical Applications of Laser.

Text & Reference Books:

1. *Laser Spectroscopy. Vol 1: Basic Principles, 5/e by W. Demtröder (Springer Nature).*
2. *Laser Spectroscopy. Vol 2: Experimental Techniques, 5/e by W. Demtröder (Springer Nature).*
3. *Introduction to Laser Spectroscopy, 5/e by Halina Abramczyk (Elsevier B.V.)*
4. *Laser Spectroscopy edited by Steven Chu, Vladan Vuletic, Andrew J. Kerman & Cheng Chin (World Scientific, USA)*
5. *Atom, Laser and Spectroscopy, 2/e by S. N. Thakur and D. K. Rai (PHI Learning Pvt. India)*
6. *Laser-Induced Breakdown Spectroscopy 1/e , edited by Jagdish P. Singh and Surya N. Thakur (Elsevier Science, USA)*
7. *Laser-Induced Breakdown Spectroscopy edited by Sergio Musazzi and Umberto Perini (Springer, UK)*
8. *Handbook of Laser-Induced Breakdown Spectroscopy, 1/e by L.J. Radziemski and David Cremers (Wiley, USA).*

Paper – IV: ELECTRONIC SPECTRA OF DIATOMIC MOLECULE PHY654

Unit-I: Review of electronic spectra of diatomic molecules, Deslander's table, Franck Condon Principle.

Unit-II: Thermal Distribution of quantum state's, Intensity of molecular band in electronic spectra. Effect of nuclear spin on the intensities of fine structure of electronic bands.

Unit-III: Classification of Molecular States, Multiplet Structure, Coupling and Uncoupling phenomena, Selection Rules for Electronic Transitions.

Unit-IV: Building up Principles. Electronic Configuration in diatomic molecule, Molecular Orbital Theory.

Unit-V: Basic concept of continuous and diffused spectra, Determination of heats of dissociation.

Text & Reference Books:

1. *Molecular Spectra and Molecular Structure. Vol 1: Infrared and Raman Spectra, by Herzberg (Springer).*
2. *Molecular Spectra and Molecular Structure. Vol 2: Spectra of Diatomic Molecules by Herzberg (Springer).*
3. *Atomic and Molecular Spectroscopy: Basic Aspects and Practical Applications by Sune Svanberg (Springer)*
4. *Introduction to Molecular Spectroscopy by Gordon M. Barrow (McGraw-Hill)*
5. *Molecular Physics: Theoretical Principles and Experimental Methods by W. Demtröder (Wiley-VCH Verlag).*
6. *Molecular Spectroscopy: Modern Research by K. N. Rao(Academic Press)*
7. *Molecular Spectra by Banwell (Mc Graw Hill).*
8. *Molecular Spectra by J. D. Graybeal (Mc Graw Hill).*

SEMESTER-IV

Paper-I: EXPERIMENTAL TECHNIQUES & CONTROL SYSTEMS PHY603

Unit-I: Data Interpretation and Analysis: precision and accuracy, error analysis, propagation of errors, least squares fitting, linear and non linear curve fitting, chi-square test.

Unit-II: Optoelectronic Devices and Detectors: Solar cells, Photo-detector, Transducers (Temperature, Pressure, Vacuum pumps and Gauges).

Unit-III: Measurement and Control systems: Signal conditioning and recovery impedance matching. Ideal operational amplifier, characteristics and applications; Inverting and non inverting amplifier, integrator, differentiator, adder and comparator.

Unit-IV: Analogue v/s digital data: Statement of sampling theorem, A/D converters (Flash converters, single slope, double slope and successive approximation converter), D/A converter(R-2R ladder type and weighted resistor type converter), Digit filter (tapped delay line filter).

Unit-V: Fourier Transforms and lock-in detector, Box car averaging. Microprocessor and microcontroller basics, Instruction set related MOV, MVI and I/O commands. Addressing I/O devices (Memory mapped & I/O mapped I/O).

Text & Reference Books:

1. *Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements by John R. Taylor (Publisher University Science Books)*
2. Optoelectronic Devices and Systems by S. C. Gupta (Prentice Hall India Learning Private Limited).
3. *Hand Book of Electronics, 38/e by S. L. Gupta & V. Kumar (Pragati Prakashan).*
4. *Electronic Device & Circuits, 3/e by J. Milliman & C.C. Halkias (McGraw-Hill).*
5. *Modern Digital Electronics 4/e by R.P. Jain (Tata McGraw - Hill Education).*
6. *Microprocessor Architecture Programming & Applications with the 8085, 6/e by R.S. Gaonkar, (Penram Intl. Publishing india Pvt. Ltd.).*
7. *Microprocessor 8085 and Its Interfacing, 2/e by S. Mathur (PHI Learning).*
8. *Electronic Device & Circuits by A. Mottershead (PHI Learning).*
9. *Electronic Fundamentals and Applications, 5/e by J.D. Ryder (PHI Learning).*
10. *Digital Integrated Electronics by H. Taub & D. Schilling (McGraw-Hill).*
11. *Digital Principles and Applications by A.P. Malvino & D.P. Leach (McGraw-Hill).*
12. *Digital Logic and Computer Design by M. Morris Mano (PHI Learning).*
13. *Microelectronics by J. Millman and A. Grabel (McGraw-Hill).*

Paper-II

ELECTIVE PAPER

Elective – I

NANOBIOTECHNOLOGY **PHY663**

Unit-I: Biological Nano-Objects
Structural and Functional Regulation of DNA: Geometry, Topology and Methylation : Geometry of the DNA Double Helix - The Z Conformation of DNA.- Supercoiled DNA - Methylation of DNA - Protein–Lipid Assembly and Biomimetic Nanostructures : Introduction: Biological Membranes - Lipid Membranes: Structure and Properties - Models and Methods for Characterising Membranes - Protein–Lipid Assembly - Applications of Biomimetic Membranes

Unit-II: Functionalized Inorganic Nanoparticles FOR Biomedical Applications and Living Machines
Synthesis and Chemical Surface Modification of Inorganic Nanoparticles – Biological Tagging in Vitro and in Animals - *In-Vivo* Applications - Living Nanomachines: Introduction - Force and Motion by Directed Assembly of Actin Filaments - Molecular Motors: Myosins and Kinesins - ATP Synthase.

Unit-III: Methods of Nanobiotechnology
Optical tools – Nanoforce and imaging – Surface methods – Mass spectrometry – Electrical Characterization and Dynamics of Transport – Microfludics : Concepts and Applications to the Life Sciences.

Unit-IV: Applications of Nanobiotechnology
Real Time PCR – Biosensors : From the Glucose electrode to the Biochip – DNA Microarrays – Protein Microarrays – Cell Biochips – Lab on a chip – Polyelectrolyte multilayers – Biointegrating materials – Pharmaceutical applications of nanoparticles carriers.

Unit-V: Major Physiologic Systems of Current Interest to Biomedical Engineers
Cardiovascular, endocrine, nervous, visual, auditory, gastrointestinal, and respiratory. Useful definitions. The status of tissue engineering of specific organs, including bone marrow, skeletal muscle, and cartilage. Cell biological fundamentals of tissue engineering. Nanoparticle-biomaterial hybrid systems Biomaterial based metallic nanowires, networks.

Text & Reference Books:

1. *Nanoscience : Nanobiotechnology and Nanobiology, P. Boisseau, P. Houdy and M. Lahmani, Springer, 2007.*
2. *Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology, Hari Singh Nalwa, American Scintific Publishers, 2005.*
3. *Nanobiotechnology, C.M.Niemeyer, C.A. Mirkin, Wiley VCH, 2004.*

4. *Nanocomposite Science & Technology, Ajayan, Schadler & Braun, Wiley VCH, 2005.*
5. *Nanoelectronics and Nanosystems: From Transistors to Molecular Devices, K.Goser, P. Glosekotter, J. Dienstuhl, Springe, 2004.*
6. *Nanotechnology: Basic Science and Emerging Technologies, Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons, Burkhard Raguse, Overseas Press, 2005.*
7. *Nanobiotechnology: Concepts, Applications and Perspectives, Christof M.Niemeyer, Chad A.Mirkin, Wiley-VCH, Weinheim, 2004.*
8. *Bionanotechnology : Lessons from Nature, David S. Goodsell, Wiley-Liss, 2004.*
9. *NanoBiotechnology Protocols, Sandra J. Rosenthal, David W.Wright, Humana Press, New Jersey, 2005.*
10. *Protein Nanotechnology, Protocols, Instrumentation and Applications, Tuan Vo-Dinh, Humana Press, New Jersey, 2005.*

Elective – II

LASER FUNDAMENTALS AND APPLICATIONS **PHY664**

Unit-I: Properties of Lasers & Einstein Coefficients and Light Amplification
Laser Beam Characteristics, Coherence Properties of Laser Light, Temporal, Spatial Coherence. The Einstein Coefficients: Absorption and Emission Cross Sections, Light Amplification, The Threshold Condition, Line Broadening Mechanisms (Natural, Collision, Doppler Broadening), Saturation Behavior of Homogeneously and Inhomogeneously Broadened Transitions, Quantum Theory for the Evaluation of the Transition Rates and Einstein Coefficients, More Accurate Solution for the Two-Level System.

Unit-II: Laser Rate Equation & Optical Resonators
Laser Rate equation, *Two-Level System*, *Three-Level Lase*r System, The Four-Level Laser System, Variation of Laser Power around Threshold, Optimum Output. Optical Resonators: Modes of a Rectangular Cavity and the Open Planar Resonator, Spherical Mirror Resonators, The Quality Factor, The Ultimate Linewidth of a Laser, Mode Selection (Transverse and Longitudinal Mode Selection), Pulsed Operation of Lasers, Q-Switching, Techniques for Q-Mode Locking, Modes of Confocal Resonator System, Modes of a General Spherical Resonator.

Unit-III: Some Laser Systems
Ruby Lasers, Neodymium-Based Lasers, Nd:YAG Laser, Nd:Glass, Titanium Sapphire Laser, The He–Ne Laser, The Argon Ion Laser, The CO2 Laser, Dye Lasers, Semiconductor Lasers. Optical Parametric Oscillators: Introduction, Optical Non-linearity, Parametric Amplification, Singly Resonant Oscillator, Doubly Resonant Oscillator, Frequency Tuning, Phase Matching.

Unit-IV: Application of Laser in Light Wave Communications
Carrier Wave Communication, Analog Modulation, Digital Modulation, Optical Fibers in Communication, The Optical Fiber, Why Glass Fibers?, Attenuation of Optical Fibers, Aperture of the Fiber, Multimode and Single-Mode Fibers, Single-Mode Fiber, Spot Size of the Fundamental Mode, Pulse Dispersion in Optical Fibers.

Unit-V: Application of Laser in Science & Industry
Second-Harmonic Generation Stimulated Raman Emission, Intensity-Dependent Refractive, Lasers in Chemistry, Lasers and Ether Drift, Lasers and Gravitational Waves, Rotation of the, Photon Statistics, Lasers in Isotope Separation. Applications in Material Processing: Laser Welding, Hole Drilling, Laser Cutting. Other Applications: Laser Tracking, Lidar. Lasers in Medicine. Precision Length Measurement Laser Interferometry and Speckle. Speckle Metrology. Velocity Measurement: Lasers in Information Storage, Bar Code Scanner.

Text & Reference Books:

1. *Lasers: Fundamentals and Applications by K. Thyagarajan and Ajoy Ghatak (Springer US)*
2. Basics of Laser Physics by Karl F. Renk (Springer-Verlag Berlin Heidelberg)
3. *Principles of Lasers by Orazio Svelto(Springer US)*
4. *Principle of Lasers and Optics by Willium S.C. Chang (Cambridge University Press)*
5. *Handbook of Lasers by Marvin J. Weber (CRC Press LLC).*
6. *Fundamentals of Light Sources and Lasers by Mark Csele (Published by John Wiley & Sons, Inc., Hoboken, New Jersey).*

Elective – III

PROGRAMMING FOR UMERICAL METHODS **PHY665**

Unit-I: C++ keywords: various data types, implicit conversions, for loop, while and do-while loop, break and continue statements, switch statement, if else, conditional operator, functions with default arguments, function overloading.

Unit-II: ++ and – operators, Arrays, Structures, Pointers, Compound assignment.

Unit-III: Basic concept of OOP: definition of class and object, declaration of classes and objects, simple applications.

Unit-IV: Programming in C++ for the following: Newton Raphson method, Iterative method, Integration by Trapezoidal and Simpson 1/3 rule, Interpolation, Matrix manipulations.

Unit-V: Programming in C++ for Euler's method, Runge Kutta (second order and fourth order) method, phase space trajectory, equilibrium points, stability analysis.

Text & Reference Books:

1. *Object Oriented Programming in Turbo C++ by R. Lafore (Pearson Education India)*
2. *Methods of Numerical Analysis 5/e, by S. S. Sastry (Prentice Hall India Learning Private Limited)*
3. *Handbook of Lasers by Marvin J. Weber (CRC Press LLC).*

Elective – IV

GROUP THEORY **PHY666**

Unit-I: Group theory and its application: Abstract definitions: Group, Multiplication Table, Sub-groups, Isomorphism and homomorphism, complexes, Cosets and classes, Indirect-group, Direct product of groups.

Unit-II: Theory of Representation :Linear vector space, basis, matrix representation of operators, unitary space, Unitary matrices, representation of group, characters, reducible and irreducible representations, Invariant subspaces, Schur's Lemmas

Unit-III: Orthogonality theorem for irreducible representation and characters Regular representation, occurrence of, an irreducible representation in a reducible representation.

Unit-IV: Theorem for possible number of irreducible representations of a group. Direct product of representations. Relationship to Quantum mechanics: Symmetry transformations, degeneracy and invariant subspaces, projection operators, transformation of functions.

Unit-V: Applications to molecular and crystal symmetry, Fundamental point group operations and nomenclature, construction of thirty-two point groups and character tables for their irreducible representations.

Text & Reference Books:

1. *Group Theory and Quantum Mechanics by Michael Tinkham (Dover Publication).*
2. *Molecular Symmetry and Group Theory* by *Robert L. Carter (Wiley)*
3. *Group Theory and Its Applications in Physics by Teturo Inui, Yukito Tanabe, Yositaka Onodera (Springer)*
4. *Group Theory and Its Application to Physical Problems by Morton Hamermesh (Dover Publication).*

Specialization-I: Nanoscience & Nanotechnology

Paper: III: MICRO AND NANOFABRICATION PHY668

Unit-I: Basic Microfabrication Techniques

Basic Microfabrication Techniques: Lithography - Thin Film Deposition and Doping : Oxidation – Doping – Chemical Vapor Deposition and Epitaxy – Physical Vapor Deposition – Electroplating - Etching and Substrate Removal : Wet Etching – Dry Etching – Substrate Bonding : Si Direct Bonding – Anodic Bonding – Bonding with Intermediate Layers.

Unit-II: MEMS and NEMS

MEMS Fabrication Techniques: Bulk Micromachining - Surface Micromachining - High-Aspect-Ratio Micromachining - Nanofabrication Techniques: e-Beam and Nano-Imprint Fabrication - Epitaxy and Strain Engineering - Scanned Probe Techniques - Self-Assembly and Template Manufacturing.

Unit-III: Material Aspects and Applications of MEMS/NEMS

Silicon - Germanium-Based Materials – Metals - Harsh Environment Semiconductors - GaAs, InP, and Related III-V Materials - Ferroelectric Materials - Polymer Materials - Future Trends - MEMS Devices and Applications - NEMS Devices and Applications - Current Challenges and Future Trends.

Unit-IV: Clean Room

Clean room standards – Clean room sub systems – Environment, Safety and Health Aspects.

Unit-V: Process Integration

Junction and Oxide Isolation – LOCOS Methods – Trench Isolation – Silicon on Insulator Isolation Techniques – Semi insulating Substrates – Schottky Contacts – Implanted Ohmic Contacts – Alloyed Contacts – Multilevel Metallization – Planarization and Advanced Interconnect.

Text & Reference Books:

1. *Springer Handbook of Nanotechnology, Bharat Bhushan, Springer, 2004.*
2. *Introduction to Microfabrication, Sami Franssila, John Wiley & Sons Ltd, 2004.*
3. *The Science and Engineering of Microelectronic Fabrication, Stephen A. Campbell, Oxford University Press 2001.*
4. *Microfabrication and Nanofabrication, Mark J. Jackson, CRC Taylor & Fancis, 2006.*
5. *Nano and Microelectromechanical Systems : Fundamentals of Nano and Microengineering, Sergey Edward Lyshevski, CRC Press, 2001.*

Paper: IV: APPLICATIONS OF NANOTECHNOLOGY PHY668

Unit-I: Sensors

Sensors - Nanotechnology Enabled Sensors - Sensor Characteristics and Terminology - Static and Dynamic Characteristics; Inorganic Nanotechnology Enabled Sensors - Gas Sensing with Nanostructured Thin Films - Phonons in Low Dimensional Structures - Nanotechnology Enabled Mechanical Sensors - Nanotechnology Enabled Optical Sensors - Magnetically Engineered Spintronic Sensors; Organic Nanotechnology Enabled Sensors - Surface Interactions - Surface Materials and Surface Modification - Proteins in Nanotechnology Enabled Sensors - Nano-sensors based on Nucleotides and DNA.

Unit-II: Energy Devices

Solar Cells - Band Diagram and Operational Principle of Nanocrystalline Solar Cells - The Importance of the Nanostructure - Quantum Dot Sensitizer; Electrochemistry and Nanoscale Materials - Electrochemistry and Size Effects - Challenges of Charge Transfer - Nanomaterials and Nanostructured Films as Electro active Electrodes - Nanomaterials as Electrolytes - Nanoscale Electronic and Ionic Transport – Energy Conversion and Storage in Electrochemistry - Overview of the Principles of Operation of Energy Conversion and Storage Devices - Lithium Ion Batteries - Fuel Cells - Photoelectrochemical Solar Cells - Electrochemical Double-Layer Capacitors - What Relevance Has Nanotechnology for Fuel Cell Systems - Fuel Cell Technology and Nanotechnology.

Unit-III: Potential Defence Applications

Military applications of Nanotechnology - Electronics, photonics, magnetic - Computers, Communication - Software/Artificial Intelligence – Materials -Energy Sources, Energy Storage - Propulsion – Vehicles - Propellants and Explosives – Camouflage -Distributed Sensors - Amour, Protection - Conventional Weapons - Soldier Systems - Implanted Systems, Body Manipulation - Autonomous Systems - Mini-/Micro Robots - Bio-technical Hybrids - Small Satellites and Space Launchers - Nuclear Weapons - Chemical Weapons - Biological Weapons - Chemical/Biological Protection.

Unit-IV: Nanostructured Food and Packaging Materials

Natural Food Nanostructures - Naturally Occurring Food Nanosubstances and Nanostructures - Designing Food Nanostructures - The Status of Natural Nanostructures in Food - Nanomaterials for (Health)food Applications - Nano-sized Food Ingredients and Additives in Relation to Digestion of Food - Nanotechnologies in Food Packaging - Improvement of Mechanical Properties through Nanocomposites - Improvement of Barrier Properties - Improvement of the Performance of Bio-based Polymers - Surface Biocides - Active Packaging Materials - Intelligent Packaging Concepts.

Unit-V: Biomedical Applications and Nanoparticles in Drug Delivery

Magnetic Nanoparticles as Contrast Agents for Medical Diagnosis - Nanoparticles in Medicine - Size-Dependent Effects of Magnetic Particles – Preparation - Methods for Iron Oxide Nanoparticles and *in-vitro* Characterization – *in- vivo* Investigations - Using Nanoparticles in Animals - Magnetic Nanoparticles for Imaging and Therapy in Humans - Toxicity of Nanoparticles - Future Perspectives. Nanoparticulate Drug Delivery to the Reticuloendothelial System and to Associated Disorders – Delivery of Nanoparticles to the Cardiovascular System – Nanocarriers for the Vascular Delivery of Drugs to the Lungs – Nanoparticulate Carriers for Drug Delivery to the Brain – Nanoparticles for Targeting Lymphatics – Polymeric Nanoparticles for Delivery in the Gastro-Intestinal Tract –

Nanoparticular Carriers for Ocular Drug Delivery – Nanoparticles and Microparticles as Vaccines Adjuvants.

Text & Reference Books:

1. *Nanotechnology - Enabled Sensors, Kourosh Kalantar-zadeha and Benjamin Fry, Springer, 2008.*
2. *Nanostructured Materials for Electrochemical Energy Production and Storage, David J. Lockwood, Springer, 2009.*
3. *Nanotechnology in Biology and Medicine: Methods, Devices and Applications, Tuan Vo-Dinh, CRC Press, 2007.*
4. *Military Nanotechnology: Potential Applications and Preventive Arms Control, Jürgen Altmann, Routledge, Taylor and Francis Group, 2006.*
5. *Nanotechnologies in Food, Qasim Chaudry, Laurence Castle and Richard Watkins, RSC Publications, 2010.*
6. *Recent Trends in Fuel Cell Science and Technology, Edited by Suddhasatwa Basu, Springer (2007).*
7. *Nanomedicine, Vijay K. Varadan, Linfeng Chen, Jining Xie, A John Wiley and Sons, Ltd., Publication (2008).*
8. *Biological Nanostructures and Applications of Nanostructures in Biology : Electrical, Mechanical, and Optical Properties, Edited by Michael A. Stroscio and Mitra Dutta, Kluwer Academic Publishers (2004).*
9. *Nanoparticles as Drug carriers, Vladimir P Torchilin, Imperial College Press, USA, 2006*
10. *Nanomedicine, Parag Diwan and Ashish Bharadwaj, pentagon press, India, 2006.*

Specialization-II: Laser and Spectroscopy

Paper – III: ADVANCED ATOMIC SPECTROSCOPY **PHY669**

Unit-I: Lamb – shift in hydrogen spectrum.

Unit-II: Complex Spectra and their interpretation, nitrogen, oxygen and manganese as examples, Alternation of multiplicities, Inversion of states.

Unit-III: Breit's Scheme for spectral term derivation, Rydberg atoms and Rydberg states.

Unit-IV: Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), Inductively Coupled Plasma Mass Spectroscopy (ICP-MS), LIBS, Photo electron spectroscopy (PES), Auger Electron Spectroscopy (AES), X-Ray Fluorescence Spectroscopy (XRF).

Unit-V: Limitations of Optical Microscope and Electron Microscope, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), Scanning Tunneling Electron Microscopy (STEM), Fluorescence Microscopy.

Text & Reference Books:

1. *Atomic Spectra and Atomic Structure, 2/e by Gerhard Herzberg (Dover Publication).*
2. *Atomic and Molecular Spectroscopy: Basic Aspects and Practical Applications by Sune Svanberg (Springer).*
3. *Atomic Spectroscopy, 2/e by James W. Robinson (CRC Press).*
4. *Introduction to Atomic Spectra by H. E. White (McGraw-Hill).*
5. *Theoretical Atomic Spectroscopy, 1/e by Zenonas Rudzikas (Cambridge University Press)*
6. *Atom, Laser and Spectroscopy, 2/e by S. N. Thakur and D. K. Rai (PHI Learning Pvt. India)*
7. *Laser-Induced Breakdown Spectroscopy 1/e, edited by Jagdish P. Singh and Surya N. Thakur (Elsevier Science, USA).*
8. *Laser-Induced Breakdown Spectroscopy edited by Sergio Musazzi and Umberto Perini (Springer, UK).*
9. *Handbook of Laser-Induced Breakdown Spectroscopy 1/e,by L.J. Radziemski and David Cremers (Wiley, USA).*
10. *Handbook of Microscopy of Nanotechnology edited by Nan Yao and Zhong Lin Wang (Kluwer Academic Publishers, USA).*

Paper – IV: IR & RAMAN SPECTRA OF POLYATOMIC MOLECULES PHY670

Unit-I: Symmetry Elements and Symmetry Operations, Point Groups, Classification of Molecules into Point Groups.

Unit-II: Rotation and Rotational Spectra of Linear Polyatomic Molecules and Symmetric Top Polyatomic Molecules, Energy Levels and Symmetry Properties, Influence of Nuclear Spin and Statistics, Rotational Structure in the Far Infrared, Rotational Structure in the Raman Spectra & Alteration of Intensity.

Unit-III: Vibrational Motion, Motion in Cartesian Coordinates, Mass Weighted Cartesian Coordinates, Normal Coordinates and Normal Modes of Motion; Vibrational Energy, Infra-red and Raman Vibrational Spectra.

Unit-IV: Fermi Resonance, Several Potential Minima and Inversion in Ammonia Molecule, Torsional oscillations, Active and Inactive IR and Raman Fundamentals, Functional Group Analysis.

Unit-V: Interaction of Rotation and Vibration, Rotation Vibration Spectra of Linear Polyatomic Molecule, Energy levels and Symmetry Properties, Coriolis Interaction, IR and Raman Spectra of Linear Polyatomic Molecule.

Text & Reference Books:

1. *Molecular Spectra and Molecular Structure. Vol 3: Spectra of Polyatomic Molecules by Herzberg (Springer).*
2. *Atomic and Molecular Spectroscopy: Basic Aspects and Practical Applications by Sune Svanberg (Springer)*
3. *Introduction to Molecular Spectroscopy by Gordon M. Barrow (McGraw-Hill)*
4. *Molecular Spectroscopy: Modern Research by K. N. Rao(Academic Press)*
5. *Molecular Spectra by Banwell (Mc Graw Hill).*
6. *Molecular Spectra by J. D. Graybeal (Mc Graw Hill).*

Semester-III: Laboratory course

PHY631: Nanoscience & Nanotechnology Lab (Image Analysis)

PHY632: Nanoscience & Nanotechnology Lab (Experimental)

1. Verification of Lambert Beer's law and determination of concentration of unknown solution by UV-Vis spectrophotometer.
2. Preparation of colloidal Silver (Ag) nanoparticles with trisodium citrate and their characterization by UV-Vis spectroscopy.
3. To study Hydrogen bonding by FT-IR spectroscopy
4. Preparation of metal oxide nanoparticles by microemulsion technique
5. Characterization of prepared metal oxide nanoparticles by XRD and determination of their size by Scherrer's Equation.
6. To determine the Band-Gap of given Semiconductor using Four Probe Method from Liquid Nitrogen Temp to Room Temperature
7. Synthesis of at least two different sizes of Nickel Oxide Nano Particles Using Sol-Gel Method
8. Synthesis of at least two different sizes of Copper Oxide Nano Particles Using Sol-Gel Method
9. Synthesis of at least two different sizes of Zinc Oxide Nano Particles Using Sol-Gel Method
10. Preparation of quantum dot (ZnS) nanoparticles and estimation of band gap from band edge
11. Synthesize copper oxide nanoparticles by sol-gel method and determine the average size of nanoparticles using Zeta sizer.
12. Fabricate silver nanoparticles embedded in silica glass by ion exchange method and study surface plasmon resonance using UV-visible spectroscopy.
13. Fabricate copper nanoparticles embedded in silica glass by ion exchange method and determine the size of nanoparticles using optical absorption spectroscopy.
14. Synthesize silver nanocrystals in solution by citrate reduction method and study the effect of capping using optical absorption spectroscopy.
15. Study the growth kinetics of silver nanoparticles embedded in ion exchanged glass at different temperatures using optical absorption spectroscopy.
16. Drug administration methods
17. Determination of the particle size of the given materials using He-Ne LASER.
18. XRD analysis of the given XRD spectra.

PHY631: Laser & Spectroscopy Lab (Spectra Analysis)

PHY632: Laser & Spectroscopy Lab (Experimental)

Semester-IV: Thesis /Dissertation PHY633