ANNEXURE - IV

DEPARTMENT OF PHYSICS

PONDICHERRY UNIVERSITY

Revised Syllabus of

Two-year M.Sc. (Physics) Program

also common to 4th and 5th year of
Integrated 5-year M.Sc. (Physics)

2022-23 Onwards

PHYS 430 Laboratory **[3 credits]**

General Experiments

1. Resistivity measurement by four probe method.
2. Study of Frank Hertz experiment.
3. Study of ferro-electric phase transition.
4. Study of Hall effect.
5. Constant Deviation Spectrometer.
6. Hysteresis loop of ferromagnetic materials.
7. Determination of magnetic susceptibility of a solid by Guoy's method.
8. Photoconductivity
9. Dielectric constant
10. Michelson Interferometer
11. Diffraction grating experiment
12. Zeeman Effect

Electronics Experiments

1. Bipolar junction transistor – Common emitter amplifier.
2. Bipolar junction transistor – Two stage RC-coupled amplifier.
3. Characteristics of FET.
4. Study of unijunction transistor.
5. Study of phase shift oscillator.
6. Study of Hartley oscillator.
7. Study of Colpitt's oscillator.
8. Operational amplifier characteristics.
9. Frequency response of an operational amplifier.
10. Configurations of an operational amplifier.

Text Books

1. V. Y. Rajopadhye and V. L. Purohit. Text book of experimental physics.
2. H. Singh. B.Sc practical physics. S. Chand & Co.
3. T. C. Hayes and P. Horowitz. Students manual for the art of electronics. Cambridge University Press.
4. Sanish Kumar Gosh. A text book of practical physics. New Central Books.
5. J. P. Holman. Experimental methods for engineers. Tata McGraw Hill.
6. L. K. Maheswari. Laboratory manual for introductory electronics experiments. New Age International.
7. Srinivasan and Balakrishnan. A text book of practical physics. Vols. I, II. S. Viswanathan Publishers.
8. D. Chatopadhyay and P. C. Ratshit. An advanced course in practical physics. New Central Books.
9. B. Ghosh. Advanced practical physics. Vols. I, II. Sreedhar Publishers.

PHYS 431- MATHEMATICAL METHODS IN PHYSICS - I

(4 credits - 60 hours)

Unit I: Differential Equations (15 hours)

Ordinary differential equations with constant and variable coefficients - Euler equation – Singular point of ODE - Frobenius method and series solution of second order ODE– Orthogonal functions - Strum- Liouville problem and orthogonal eigenfunction expansions – Application to solve boundary value problems - Partial Differential Equations in the curvilinear coordinate system - Heat equation, wave equation, and Laplace equation in different coordinate systems - Method of separation of variables in cartesian and curvilinear coordinate systems.

UNIT II: Special Function (15 hours)

Beta, Gamma, Delta, and Error functions and evaluation of improper integrals – Stirling's formula - Bessel, Hermite, Legendre, Associated Legendre, and Laguerre differential equations and their solutions by series method – Bessel functions of the first and second kind – Legendre polynomials, Legendre functions of the first and second kind - Spherical harmonics – Orthogonality conditions of special functions - Generating functions, Rodrigue formula, and Recurrence relations - Applications in physics.

Unit III: Complex Variables (15 hours)

The function of a complex variable – Mapping by exponential function – Differentiability and analyticity - Cauchy-Riemann conditions in polar coordinates – Analytic functions and harmonic functions – Logarithmic function and branch cuts – Contour integrals involving branch cuts - Cauchy's integral theorem and integral formula – Absolute and uniform convergence of power series - Taylor, Maclaurin, and Laurent series of complex functions – Classification of singularities – Zeros, poles, and residues - Residue theorem – Cauchy residue theorem and applications – Evaluation of real integrals using complex-valued functions involving sine, cosines, and branch cut.

UNIT IV: Integral Transforms (15 hours)

Fourier analysis – Half range Fourier series – Complex notation for Fourier series - Parseval's identity – Convergence of Fourier series and Gibb's phenomenon – Solution of Laplace equation in terms of Fourier series - Finite and infinite Fourier transforms – Fourier sine and cosine transforms – Complex Fourier transforms – Fourier expansion and inversion formulas – Fourier integrals - Convolution theorem – Solving partial differential equations - Laplace transforms - Linearity and Shifting properties – Laplace transforms of (a) derivatives, (b) integrals (c) unit step, (d) periodic functions, and (e) Dirac delta functions – Derivatives of Laplace transform - Convolution integral – Solving differential and integrodifferential equations.

Textbooks

[1] V. Balakrishnan. Mathematical Physics: Applications and Problems. Springer.
[1] M. L. Boas. Mathematical Methods in the Physical Sciences, Wiley, 2005.
[2] Jain and Iyengar, Advanced Engineering Mathematics, Narosa, 2007.
[3] Potter and Goldberg. Mathematical Methods, Prentice Hall, 1987.
[4] Schaum's Theory and Problems of Complex Variable, McGraw Hill.
[5] Schaum's Theory and Problems of Fourier analysis, McGraw Hill.

Supplementary Readings

[1] Riley, Hobson, Bence. Mathematical Methods. 2006.
[2] G. Arfken, Mathematical Methods for Physicists. Academic Press, 2000.
[3] E. Kreyszig, Advanced Engineering Mathematics John Wiley, 2015.

PHYS 432 - CLASSICAL MECHANICS

(4 credits – 60 hours)

Unit I — 12 hours

Mechanics of a system of particles – Conservation laws of linear and angular momenta for systems not subjected to external forces and torques – Constraints, degrees of freedom, generalized coordinates, and generalized potentials – Classification like holonomic, rheonomic, and scleronomous constraints - Virtual displacement and the principle of virtual work and D'Alembert's principle – Derivation of Lagrange equation from D'alembert's principle - Elements of the calculus of variations – Hamilton's least action principle - Lagrangian formulation - Derivation of Lagrange equations from Hamilton's principle - Applications to solve dynamical problems – Conservation theorems and symmetry properties – Norther's theorem.

Unit II — 12 hours

Motion in a central field – Kepler's problem – Reduction to equivalent one-body problem – Equation of motion for Kepler's problem and first integrals – Classification of orbits – Differential equation for the orbit and power-law potentials – Bertrand theorem – The Laplace-Runge-Lenz vector – The concept of superintegrable systems – Scattering in a central field – Laboratory and center of mass frame – differential scattering cross section – scattering by a central field.

Unit III — 12 hours

Variational method – Legendre transformation, Hessian and Hamilton's equations of motion – Cyclic coordinates and conservation theorems - Canonical transformations and applications – Generating functions – Infinitesimal contact transformations – Lagrange and Poisson brackets and canonical invariants – Angular momentum Poisson bracket relations - Hamilton, Jacobi theory with harmonic oscillator as an example.

Unit IV — 12 hours

Degrees of freedom of a rigid body and kinematic links – Orthogonal transformations - Rigid body rotation – Finite and infinitesimal rotation of rigid bodies - Laboratory and rotating frame of reference - Euler angles - Transformation between rotating and stationary frames – Coriolis and centrifugal forces – Angular momentum and kinetic energy about a point of rotating rigid body - Moment of inertia tensor and Principal axis transformation – Euler's equations – Symmetric top precession – Theory of small oscillations – Normal co-ordinates and vibrations of a discrete system – Forced oscillations.

Unit V — 12 hours

The special theory of relativity: Inertial frames – Lorentz transformations – Length contraction, Time dilation and Doppler effect – Minkowski space – Index notation for vectors and tensors – Metric tensor – Einstein summation convection – Covariant and contravariant vectors - Energy momentum four vectors – Introduction to general relativity.

Textbooks

[1] T. Thornton and J B. Marion. Classical Dynamics of Particles and Systems. 2003.
[2] H Goldstein, C P. Poole, J L. Safko, Classical Mechanics, Addison Wesley, 2001.
[3] J L Synge and B A Griffith, Principles of Mechanics. McGraw Hill.
[4] T W B Kibble and F H Berkshire. Classical Mechanics. Imperial College Press, 2004.
[5] J C Upadhyaya. Classical Mechanics. Himalaya Publishing, 2014.

Supplementary Reading

[1] T. G. Takwale and P. S. Puranik, Introduction to classical mechanics, TMH (1980).
[2] D. T. Greenwood, Classical Dynamics, Prentice Hall. New Jersey, (1965).
[3] A. K. Raychaudri, Classical Mechanics, Oxford University Press. 1983.
[4] K. G. Gupta, Classical Mechanics of Particles and Rigid Bodies Wiley (1988).

PHYS 434 - ELECTRONIC DEVICES AND CIRCUITS

(4 credits - 60 hours)

Unit-I: Review of Semiconductor Physics 10 hours

Energy Bands in solids, Transport phenomena in Semiconductors, Intrinsic and extrinsic Semiconductors, PN junction diode, I-V characteristics using a diffusion model.

Unit-II: Semiconductor Diodes 15 hours

Operation, characteristics, and applications of Zener and Avalanche, Varactor, Schottky-barrier, Tunnel diodes - Construction, operation, and characteristics of BJT, FET, and MOSFET- FET amplifier - UJT relaxation oscillator. BJT RC coupled amplifier and its frequency response.

Unit-III: Operational amplifiers: 10 hours

Basics of differential amplifiers-Characteristics of ideal and practical opamps-Applications: inverting, non-inverting, Summing, difference, integrating, differentiating amplifiers- Signal processing circuits: precision rectifiers, clipper, clamper, and peak detectors-

Unit-IV: Signal generators and Active filters 10 hours

Signal generators and active filters - triangular and square wave generators, phase shift, and Wien bridge oscillator using opamps - Active filters: First order low pass and high pass filters, Bandpass and band elimination filters- Temperature compensated logarithmic and antilogarithmic amplifiers.

Unit – V: Optoelectronics 10 hours

Optoelectronics: Radiative and nonradiative transition, Light-dependent resistor (LDR), Photodiodes, phototransistors, Photovoltaic (Solar) cell Materials, construction and operation of the LED, Diode laser; Structure, Working and factors affecting performance.

Textbooks

[1] J.Millman and C.C.Hallkias, Integrated Electronics. Tata McGraw Hill.
[2] Boylsted and Nashelsky, Electronic Devices and Circuits, Pearson, (2009).
[3] Floyd, Electronic Devices, Pearson, Seventh Edition (2009).
[4] Simon M. Sze, Physics of Semiconductor Devices, John Wiley (2006).
[5] Wilson, Hawkes, Optoelectronics: An Introduction, PHI, Second Edition, (2003).
[6] Gillmore, Microprocessors: Principles and Applications, Mc-Graw Hill (2005).

PHYS 435 NUMERICAL METHODS (3 – 0 – 0 - 3)

(3 credits – 45 hours)

UNIT – I: Introductory Concepts 12 hours

Overview of scientific programming languages like Matlab, Fortran, and Python - Representing numbers in a computer – Floating point arithmetic – Overflow and underflow – Absolute and relative errors - Machine precision (epsilon) – Loss of significance - Robustness of numerical method - Errors in mathematical approximations – Error propagation – Lagrange polynomial interpolation – Orthogonal polynomials – Splines and B-spline interpolation – Chebyshev polynomials – Hermite interpolation - Linear versus Polynomial least squares approximation - Matrices and linear system of equations – Elementary row operations – Tridiagonal and band matrices - Symmetric positive definite matrices – Norm and condition numbers of matrices.

UNIT – II: Linear Systems 12 hours

Linear systems – Gauss elimination and pivoting - Gauss method to compute the Inverse – LU decomposition – Cholesky decomposition – QR factorization – The Gram-Schmidt algorithm – Givens rotations method – Relaxation methods – Jacobi and Gauss-Seidel iterative methods – Steepest descent method – Conjugate gradient method - Eigenvalues and eigenvectors of a real symmetric matrix by Jacobi's method – Determination of largest eigenvalue by Power method – Convergence of the above numerical methods.

UNIT – III: Differential Equations 12 hours

Taylor series and finite differences – Forward and backward difference tables for first and higher order derivatives – Centered difference and three-point difference formulae - Euler's method for the solution of the ordinary differential equation – Convergence, stability, and error propagation in Euler's method - Runge Kutta methods with Runge's coefficients – Solving Laplace equation and Poisson equation using the finite difference method – Numerical solution of the one-dimensional heat equation.

UNIT – IV: Laboratory Tutorial 9 hours

The laboratory exercise involves writing programs in FORTRAN / MATLAB / PYTHON to solve problems of numerical techniques for the topics learned in this course.

Textbooks

[1] K Atkinson, and W Han. Elementary Numerical Analysis. Wiley, 2003.
[2] E Süli, and D F Mayers. An Introduction to Numerical Analysis. CUP, 2003.
[3] A C Faul. A Concise Introduction to Numerical Analysis. Chapman, 2016.
[4] Iyengar and Jain. Numerical Methods. New Age International, 2009.

Supplementary Readings

[1] I H Hutchinson, A Student's Guide to Numerical Methods. CUP, 2016.
[2] T Sauer, Numerical Analysis, Pearson, 2011.
[3] T Heister, L G Rebholz, and F Xue, Numerical Analysis: An Introduction, De Gruyter, 2019.
[4] R L Burden, J D Faires, Numerical Analysis, Brooks Cole, 2010.

PHYS 436: UNIX, FORTRAN-90 and C++ **(3 credits)**

UNIT – I: Unix Operating System **12 hours**

Introduction to operating system – General OS architecture – Evolution of Unix operating system – Architecture of the Unix OS – The kernel – Memory management – Virtual memory – Paging – Segmentation – Shells and GUI – Directory structure – File systems in Unix – Mount point – Processes and threads – Multi-threading – Semaphores – Mutex – CPU process scheduling – Concept of deadlock – Services and Daemons – Introduction to Networking – Network file systems – Elements of system administration – Principles of topography – Typesetting in LaTeX – Elements of bibliography and citation – The Harvard system.

UNIT – II: Fortran-90 **12 hours**

Evolution of Fortran language – Different Fortran compilers – Skeleton of a general Fortran 90 program – Free source format and character set – Specifications – Derived types – Control Structure – CASE construct – New features of DO loop: EXIT, CYCLE statements, Control clauses – Concept of internal, and external procedures, modules and INTERFACE blocks – Concept of scope – CONTAINS statement – Procedure Arguments – Optional arguments – Keyword arguments – Recursive procedures – Modules – Array Processing – Terminology and Specifications – Whole array operations – Vector subscripts – Array assignment – Array constructor – Allocatable dynamic array – Pointers and Dynamic Data Structures – Concept of pointers – Example programs.

UNIT – III: C++ **12 hours**

Introduction – Algorithms – Control Structures – if Selection Statement – if-else statement – do-while repetition Statement – Nested Control Statements – Assignment Operators – Increment and decrement operators – break and continue Statements – Logical Operators – C++ math library functions – Function definitions with multiple parameters – Function prototypes – C++ standard library header files – Random Number Generation – Inline functions – Arrays – Declaring arrays – Examples using Arrays – Passing arrays to functions – Pointer variable declarations and initialization – Pointer Operators – Passing arguments to functions by reference with pointers – Using `const` with pointers – Introduction to operator overloading.

UNIT – IV: Laboratory Exercise Session **12 hours**

The following exercises have to be done in Fortran 90 or in C++ : Swapping of two numbers – Counting – Factorial Computation – SINE computation – Base Conversion – Factoring Methods – Array Techniques – Display the Pascal Triangle – Generate prime numbers between 1 to N – Generate Fibonacci series up to N number – Concatenating two strings – Reversing the string – Finding the substring of a given string – Summation of a sin, cos and exponential series – Matrix computations – Random number generation.

Textbooks

1. Jerry Peek, Grace Todino-Gonguet, John Strang, Learning the UNIX Operating System, O'Reilly Media, Inc. (2002) Fifth Edition.
2. F. Mittelbach, M. Goossens, J. Braams, D. Carlisle, C. Rowley, LaTeX Companion, Addison-Wesley (2004), Second Edition.
3. Stephen Chapman, Fortran 90 / 95 for Scientists and Engineers, McGraw Hill (2003) Second Edition
4. Harvey M. Deitel and Paul J. Deitel, C++ How to Program, Prentice Hall (2007) Sixth Edition.

Supplementary Reading

1. W. S. Brainerd, C. H. Goldberg and J. C. Adams, Programmer's Guide to Fortran 90, Springer (1995): Michael Metcalf and John K. Reid, Fortran 90/95 Explained, Oxford University Press (1999).
2. Michael Metcalf, John Reid and Malcolm Cohen, Fortran 95 / 2003 Explained (Numerical Mathematics and Scientific Computation), Oxford University Press (2004).
3. Bjarne Stroustrup, The C++ Programming Language, (2000) Third Edition.

PHYS 437: DIFFERENTIAL EQUATIONS and TRANSFORM TECHNIQUES (3 credits)

UNIT – I: Ordinary Differential Equations **12 hours**

First order ODE's – Separable ODE's – Orthogonal trajectories – Physical modeling – Second order linear ODE's – Differential operators – Physical modeling – Higher order linear ODE's – Homogeneous and inhomogeneous differential equations – Series solution of ODE's – Frobenius method – Strum-Liouvllie problem – Orthogonal eigenfunction expansions.

UNIT – II: Partial Differential Equations **12 hours**

Introduction to partial differential equations – Introduction to curvilinear coordinates – Cylindrical polar and spherical polar systems – Review of vector calculus – Divergence, curl and Grad in polar system – Solution by analytical methods – Solution of (i) Laplace, (ii) Poisson, (iii) Helmholtz wave and (iv) diffusion equations in Cartesian and polar coordinate systems.

UNIT – III: Laplace Transforms **12 hours**

Laplace transforms – Inverse transforms – Linearity and Shifting theorems – Laplace transform of derivative of a function – Laplace transform of integral of a function – Unit-step function – *t*-shifting – Short impulses – Dirac-delta function – Convolution – Integral equations – Application to solve differential equations.

UNIT – IV: Fourier Transforms **12 hours**

Introduction to Fourier analysis – Half range Fourier series – Harmonic analysis and applications – Forced oscillations – Finite and infinite Fourier transforms – Fourier sine and cosine transforms – Complex Fourier transforms – Fourier expansion and inversion formulas – Convolution theorem – Applications to solutions of partial differential equations.

Textbooks

1. G. Arfken, Mathematical Methods for Physicists Academic Press (2000) Fifth Edition.
2. Erwin Kreyszig, Advanced Engineering Mathematics John Wiley (2005) Ninth Edition.
3. R.K. Jain, S.R.K. Iyengar, Advanced Engineering Mathematics Narosa (2007) Third Edition.

Supplementary Reading

1. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical Methods for physics and engineering, Cambridge Univ. Press (1998).
2. M. P. Boas, Mathematical Methods in the Physical Sciences, Wiley(2005) Third Edition.
3. Potter M C and Goldberg, J Mathematical Methods, Prentice Hall (1988).
4. Sokolnikoff I S and Redheffer R M, Mathematics of Physics and Modern Engineering, McGraw Hill (1966) Second Edition.
5. Spiegel M R., Schaum's Outline of Theory and Problems of Complex Variable, McGraw Hill (1964).
6. Spiegel M R., Schaum's Outline of Theory and Problems of Fourier analysis, McGraw Hill (1974).

PHYS 440 LABORATORY **[3 credits]**

General Experiments

1. Determination of Lande's g factor of electron by ESR.
2. Study of Geiger-Muller counter: Study of Attenuation coefficient
3. Study of Geiger-Muller counter: Absorption of Gamma rays
4. Fourier analysis of a square wave.
5. Study of superconductivity.
6. Microwaves bench: Study of standing waves and measure the wavelength of microwave source
7. Microwaves bench: Study of Fabry-Perot interferometer
8. Study of Chuha's circuit.
9. X-ray Diffraction: study of simple cube system
10. Cooling curve
11. Transition temperature of YBCO Superconductor
12. Piezoelectric effect

Electronics Experiments

1. Integrator and differentiator using operational amplifier.
2. Wein bridge oscillator using operational amplifier.
3. Study of comparator using operational amplifier.
4. Study of multivibrators using operational amplifier.
5. Logic gates and boolean algebra.
6. Half and full adder using logic circuits.
7. Decoders using logic circuits.
8. Study of flip flops.

Text Books

1. V. Y. Rajopadhye and V. L. Purohit, Text book of experimental physics.
2. H. Singh, B.Sc practical physics. S. Chand & Co.
3. T. C. Hayes and P. Horowitz, Students manual for the art of electronics. Cambridge University Press.
4. Sanish Kumar Gosh, A text book of practical physics. New Central Books.
5. J. P. Holman. Experimental methods for engineers, Tata McGraw Hill.
6. L. K. Maheswari, Laboratory manual for introductory electronics experiments. New Age International.
7. Srinivasan and Balakrishnan, A text book of practical physics, Vols. I, II. S. Viswanathan Publishers.
8. D. Chatopadhyay and P. C. Ratshit, An advanced course in practical physics, New Central Books.
9. B. Ghosh, Advanced practical physics, Vols. I, II. Sreedhar Publishers.

PHYS 441 - QUANTUM MECHANICS - I (4 - 0 - 0 - 4)

(4 credits – 60 hours)

Unit – I (12 hours)

Review of Stern-Gerlach experiment and inadequacy of classical theory – Wave-particle duality – Wave packets – Fourier Transforms – Postulation of Time-dependent Schrödinger Equation in three-dimension – Time Independent Schrödinger Equation – Physical interpretation of wave function – Continuity Equation – Expectation values – Ehrenfest's Theorem– Dirac's Bra and Ket vectors – Heisenberg's uncertainty relation – Postulates of Quantum Mechanics – Superposition principle – Schrödinger picture – Heisenberg picture (matrix mechanics) – Interaction picture – Relation among different views.

Unit – II (12 hours)

Definition of bound states and scattering states – One-dimensional potentials – Calculation of reflection and transmission coefficients for the following problems – Dirac-delta potential – Potential step – Infinite square well – Finite square well (or potential well) – Potential barrier and quantum tunneling effect.

Unit – III (12 hours)

One dimensional harmonic oscillator – Solution of 1-D harmonic oscillator problem by analytical method (Hermite polynomials) – Eigen functions and energy eigenvalues harmonic oscillator by operator method – Annihilation (lowering) and creation (raising) operators – Solution of a linear harmonic oscillator using (a) Schrödinger picture and (b) matrix mechanics – Matrix representation of harmonic oscillator operators – Schrodinger equation in the spherical coordinate system – Angular equation – Legendre polynomials and spherical harmonics – Radial equation – Spherical Bessel function and spherical Neumann function – Solution of hydrogen atom radial equation by power series method – Derivation of Bohr formula.

Unit – IV (12 hours)

Basics of discrete Symmetries – Symmetries, Conservation Laws, and degeneracy – Parity or Space Inversion – Quantum mechanical definition of angular momentum – Angular momentum operator algebras – Ladder operators and the spectrum of eigenvalues – Commutation relations – Eigenvalues and Eigen functions of angular momentum operator – Matrix representation of angular momentum operators (basics concepts) – Spinor matrix and Pauli spin matrices – Spin of two spin- particles – Addition (coupling) of angular momenta – Clebsch- Gordan coefficients.

Unit – V (12 hours)

Time independent perturbation theory – Non-degenerate and degenerate perturbation theories – The fine Structure of hydrogen – Linear Stark effect – Zeeman effect in hydrogen – Variational method – Ground state of a helium atom – WKB approximation – Tunneling through potential barriers.

Textbooks

[1] Richard L Liboff, Introductory Quantum Mechanics, Pearson Education.
[2] D J Griffiths, Introduction to Quantum Mechanics, Pearson Education.
[3] N Zettili, Quantum Mechanics: Concepts and applications, John Wiley.
[4] Leonard I. Schiff, Quantum Mechanics, McGraw-Hill.
[5] Ashok Das, Lectures on Quantum Mechanics, World Scientific.

Supplementary Readings

[1] Stephen Gasiorowicz, Quantum Physics, John Wiley & Sons.
[2] P.M. Mathews, K. Venkatesan, A Textbook of Quantum Mechanics, TMH.
[4] J J Sakuri, J Napolitano. Modern Quantum Mechanics, Addison-Wesley.
[5] V Devanathan, Quantum Mechanics, Narosa Publishing House.
[5] F Schwable, Quantum Mechanics, Springer.

PHYS 442 - CLASSICAL ELECTRODYNAMICS (4 – 0 – 0 – 4)
(4 credits – 60 hours)

UNIT – I: Special techniques in Electrostatics 15 hours
Laplace equation for electric potential – The need for Dirac-delta function – Green functions – Derivation of divergence and curl of the electric field from Coulomb's law - Boundary conditions and uniqueness theorems — Conductors and second uniqueness theorem - Electrostatic potential problems in cartesian, cylindrical, and spherical coordinate systems – Method of images – Physical systems with and without azimuthal symmetry – Solutions using spherical harmonics - Dielectric polarization - Boundary value problems with linear dielectrics The field of a polarized object - Multipole expansion for scalar electric potential — Origin of coordinates in multipole expansions – Boundary conditions for the electric field across the interface between two dielectric media.

UNIT – II: Magnetostatics and Electrodynamics 15 hours
Lorentz force law and Biot-Savart law — Scalar and vector potentials — Derivation of divergence and curl of the magnetic field from Biot-Savart law - Multipole expansion of magnetic vector potential — Calculation of field inside matter - Amperes law in magnetized materials and Auxiliary field H — Boundary conditions for the magnetic field across the interface between two magnetic media - Faraday's law and Lenz's law — Calculation of energy density in magnetic fields — Electrodynamics before Maxwell — Maxwell's correction of Ampere's law — Continuity equation - Derivation of Maxwell's equations in vacuum and in matter.

UNIT – III: Electromagnetic waves 15 hours
Electromagnetic waves in vacuum — Wave equation for *E* and *B* fields — Reflection, refraction of electromagnetic waves — Snell's law and Fresnel's law — Poynting theorem and its derivation — Electromagnetic waves in matter — Propagation of electromagnetic waves in linear media — Reflection and transmission at normal and oblique incidence — Absorption and dispersion of electromagnetic waves — Electromagnetic waves in conductors — Reflection at a conducting surface — Interference, diffraction, and polarization.

UNIT – IV: Potentials and Radiation 15 hours
Potential formulation — Scalar and vector potentials - Gauge transformations — Coulomb and Lorentz gauge — Retarded potentials of continuous charge distribution — Derivation of Jefimenko's Equations - Retarded potentials of point charges - Lienard-Wiechert potential — Fields of a moving point charge — Electric dipole radiation — Energy radiated by an oscillating electric dipole — Radiation from moving charges — Radiation fields — Derivation of Larmor formula – Magnetism as a relativistic phenomenon – Electromagnetic field tensor - Relativistic formulation of Maxwell's equations – Covariant formulation of electrodynamics 0 Maxwell's equations in tensor notation.

Textbooks
[1] David J Griffiths, Introduction to electrodynamics, Prentice Hall (1999) Third Edition.

Supplementary Reading
[1] John David Jackson, Classical Electrodynamics, John Wiley (1999) Third Edition.
[2] M N O Sadiku, Elements of Electromagnetics, Oxford University Press.

PHYS 443: SOLID STATE PHYSICS **(4 credits)**

Unit I: Crystal structure **12 hours**

Classification of solids – liquids – amorphous glassy states, characteristics and structure – Bravais lattice – simple – body centered and face centered cubic lattices – Primitive cell, Wigner-Seitz cell and conventional cell. Crystal structures and lattice with basis – Hexagonal close packed and diamond structure – point groups – space groups – Miller indices – Reciprocal lattice – Brillouin zones – crystal diffraction – Laue – Power – Rotating – crystal methods.

Unit II: Crystal Binding and Lattice dynamics. **12 hours**

Ionic cohesive energy – Covalent – Metallic Vander Waals and hydrogen bonded crystals – Vibrational modes – one, two and three dimensional lattices – Thermal conductivity – Elastic constants – Phonon dispersion relation – Localised modes.

Unit III: Free Electron Theory and Semiconductors **12 hours**

Transport properties – electronic specific heat – electrons in a periodic potential – energy band – Bloch's theorem, Kronig – Penney's theorem – Band Structure – Carrier concentrations – Intinsic semi-conductor – Imputiry states – Semiconductor states – Electrical conductivity, mobility – Magnetic field effects – Cyclotron resonance and Hall effect.

Unit IV: Superconductivity **12 hours**

Occurrence of Superconductivity – Destruction of superconductivity by magnetic fields – Meissner effect – Heat capacity – Energy gap – Microwave and IR properties – Isotope effect – Thermodynamics of the superconducting transistors – London equation – Coherence length – BCS theory of superconductivity – Qualitative treatment of DC and AC Josephson effect.

Unit V: Electrical and Magnetic Properties **12 hours**

Ferro electric crystals – Classification of polarization – Catastrophe – Landau theory of phase transition – Second order transition – First order transition soft optical phonons – Anti ferro electricity – Ferro electric domains – Piezoelectricity – Ferro electricity. Dia – paramagnetism – Quantum theory of para magnetism – ferro – Ferri – Anti ferri magnetism. Curie Neil temperature – Magnetism and susceptibility – Ferro-magnetic domains – Magnons.

Textbook

1. N. W. Aschcroft and N. D. Mermin, Solid state physics, Holt, Rineheart and Winston, New York (1976)

Supplementary Reading

1. C. Kittel, Introduction to solid state physics. John Wiley (2003) Seventh Edition.
2. A. J. Dekker, Solid state physics, MacMillan (1981).
3. Ali Omer, Elementary solid state physics, Pearson Education (1999),
4. L. V. Azaroff, Introduction to solids, Tata McGraw Hill (2008),

PHYS 444: NONLINEAR DYNAMICS (3 – 0 – 0 - 3)
(3 credits – 45 hours)

Unit I: 12 hours
Nonlinear waves – Nonlinear partial differential equations – physical examples – AKNS method – Applications of solitons - Introduction to synergetics – examples from Physics, Chemistry, Biology, Computer Science, Economics, Ecology, and Sociology.

Unit II: 11 hours
Survey of first and second-order differential equations – inhomogeneous – non-linear differential equations – linear and non-linear dynamical systems – solutions – examples from physics.

Unit III: 11 hours
Stability of solutions from nonlinear dynamics systems – phase portrait – trajectories – limit cycles – driven pendulum – Vender Pol and Duffing oscillator – bifurcations – Hopf bifurcation – period doubling route to chaos Poincare Map – Logistic Map – strange attractors – Lorentz attractor.

Unit IV: 11 hours
Oscillating chemical system – Lotka-Volterra equations – Brusselator model – Beluosov Zhabotinsky reaction chemical chaos – self-organization. Applications to Biology, predator-prey problem, morphogenesis.

Textbooks

[1] H Haken, Synergetics, Springer Berlin (1983).
[2] H Haken, Advanced. Synergetics, Springer Berlin (1983).
[3] Prigogine, Order out of chaos, Fontana (1984).
[4] P. A. Cook, Nonlinear dynamical systems, Prentice Hall New York (1994).
[5] R. Serra, Introduction to the physics of the complex system, Pergamon. 1986.

PHYS 445: MEASUREMENT SYSTEMS and DATA ACQUISITION (3 credits)

UNIT – I: Basic concepts **12 hours**

Significance of measurement – Role of instruments in industrial processes – Block representation of measurement systems – Need for calibration and standards – Instrument parameters: sensitivity, accuracy, resolution, span, range – Classification of instruments – Generalized system configuration – Functions and characteristics of instruments and measurement systems – Errors in measurement – Analysis, sources of errors and techniques for error-minimizing – Classification of instrument transducers – Input and output characteristics – Static and dynamic response – Linearity and hysteresis.

UNIT – II: Transducers and Measurement Systems **12 hours**

– Examples of (i) resistive, (ii) inductive, (iii) capacitive, (iv) thermoelectric, (v) photo-electric, (vi) piezo-electric, (vii) ionization and (viii) Hall-effect based transducers – Displacement measurement – Force and torque measurement – Pressure and sound measurement – Relationship between absolute, atmospheric and gauge pressures – Fluid flow measurement – Temperature measurement – Measurement of light – Measurement of magnetic field.

UNIT – III: Signal conditioning and circuits **12 hours**

The need for signal conditioning – Requirements and characteristics of signal conditioners – DC and AC bridge circuits – Operational amplifiers in instrumentation – Unity gain buffer – Instrumentation amplifier – Log and antilog amplifiers – Constant current source – Voltage and current conversion – Passive and active filters.

UNIT – IV: Data acquisition and Virtual Instrumentation **12 hours**

Introduction to RS232, RS485 – Basics of Interfacing – IEEE 488.2 standards and GPIB – Introduction to USB, PCMCIA, VXI, SCXI, PXI – Historical Perspective and advantages of Virtual Instrumentation (VI) – Defining VI – Block Diagram & architecture of VI – Data Flow Techniques – Graphical Programming in Data Flow – Comparison with conventional programming – Introduction to LabVIEW.

Textbooks

1. T. G. Beckwith, R. D. Marangoni, J. H. Lienhard, Mechanical Measurements, Prentice Hall (2006), Sixth Edition. – [Units-I, II].
2. J. A. Blackburn, Modern Instrumentation for Scientists and Engineers, Springer (2001) [Unit-III].
3. Bruce Mihura, LabVIEW for Data Acquisition, Prentice Hall (2001) [Unit-IV].

Supplementary reading

1. Ernest O Doebelin, Measurement Systems: Application and Design, Tata McGraw Hill, Fifth Edition.
2. Albert D Helfrick and William D Cooper, Modern Electronic Instrumentation and Measurement Techniques, Prentice Hall of India Private Limited, New Delhi (1992)
3. Hermann K P Neubert, Instrument Transducers: An introduction to their performance and design. Oxford University Press (2003).

PHYS 446 MICROPROCESSORS AND APPLICATIONS (3 credits)

Unit I: Architecture of 8 bit Microprocessor **12 hours**

Addressing modes – instruction and times – classification – machine control operator – FORMAT – Types of memory –R/W, (RAM) – ROM, PROM, EPROM, EEPROM – I/O interfacing and addressing – display and keyboard interfacing and programming – interrupts, stacks, subroutines, 8155, 8355, 8212 clock generator and bus drives

Unit II: Assembly Language Programming **12 hours**

Programming exercise for 8085 – involving addition, subtracting and logical operations only – Monitor programme – assemblers, basic interpreters. Serial and parallel data transmission: Perriperheral chips – intel 8275, 8279, USART, instrumentation buses, RS232C, IEEE488 bus CAMAC buses.

Unit III: Digital Interfacing **12 hours**

KB, displays optical motor shift encoders – analogue interfacing D/A and A/D converters – process control – digital filters.

Unit IV: Trends in Microprocessor Technology **12 hours**

16 bit CPU, 8086, 8088 – 8086 internal architecture. Assembly language programming of 8086 – simple sequence programs Flags Jumps while – Do implementation IF – THEN, IF-THEN-ELSE and multiple – IF-THEN-ELSE programme – 8086 instruction and assembly direction. Computer systems peripherals, Raster scan, CRTs vector scan CRTs – Floppy disk controllers, hard disk interfacing Data communication networks – serial data transmission mode IBM PC architect.

Textbooks

1. Ramesh S. Goanker, Microprocessor architecture, programming and applications with 8085/8085A, Wiley Eastern (1989)
2. Douglas V. Hall, Microprocessors and interfacing. McGraw Hill (1986).
3. L. A. Leventhal. Assembly language programming. Prentice Hall (1981).
4. Kenneth L. Sherl, Microprocessors and programmed logic, Prentice Hall.
5. G. V. Rao, Microprocessors and microcomputer system, Van Nostrand Reinhold (1978)

PHYS 447: BASICS OF ASTRONOMY AND ASTROPHYSICS

(3 Credits – 45 hours)

Unit I: Astronomy 11 hours

Coordinate System- Spherical Trigonometry, Precision, Time, Heliocentric Corrections, Methods of observations, Telescopes at different wavelengths, Detectors at different wavelengths, Atmospheric effects at different wavelengths, Resolution, Background, Aberrations, Luminosity Bias, Confusion Limit Distance measurements using the parallax method, Newton's Gravitation law, and Kepler's Law in Distance and Mass Measurement.

Unit II: Stars 11 hours

Stellar Magnitudes and Colors, Brightness and distance, Luminosity, temperature and spectral class, the motion of stars relative to the Sun, the masses of stars, the Hertzsprung–Russell diagram, and main-sequence stars.

Unit III: Stellar Structure 11 hours

Equations of Stellar Structure – Solutions to Equations of Stellar Structure, Toy Stellar Models: Homologous Stellar Models, the Radiative Stellar Envelope, Fully Convective Stars with H~ Opacity, Observational Aspects of Stellar Atmospheres, Continuum Radiation, Lines.

Unit IV: 11 hours

Stellar Evolution – Pre-Main-Sequence Collapse, Evolution of High-Mass Stars, Evolution of Low-Mass Stars, Late-Stage Evolution of Stars, Supernova (Type II), White Dwarfs, Neutron Stars, and Black Holes, Pulsars, Binary Stars, and Accretion.

Unit V: 12 hours

Large Scale Structure of Universe- Hubble's Law, Galaxies and Cosmology -Evolution of the Universe, Formation of Dark-Matter Halos, Galaxy Formation, Morphological Classification of Galaxies, the Evolution of Galaxies, Active Galactic Nuclei, Features of Active Galactic Nuclei, Taxonomy of Active Galactic Nuclei, Radio Galaxies, Quasars, Luminosity Function of Galaxies and Quasars, Distribution of Matter, Extragalactic Background Radiation.

Textbooks

[1] T Padmanabhan, Theoretical Astrophysics: Vol. I-II-III, CUP (2005).
[2] W.M. Smart and R M Greene, Textbook on Spherical Astronomy, CUP (1986).
[3] Frank Shu, The Physical Universe, University of California (1982).
[4] Roy A E and Clarke D, Astronomy principles and Practice, IOP (2003).
[5] Kitchin C R, Astrophysical techniques, Institute of Physics (2003) Fourth Edition.
[6] Herwitt M, Astrophysical Concepts, Springer Verlag, (2006) Third Edition.
[7] S K Saha, Diffraction-limited imaging with large and moderate telescopes, (2007).

Supplementary Readings

[1] Chandrasekhar S, An Introduction to the Study of Stellar Structure, Dover Publications (1967).
[2] Clayton D D, Principles of Stellar Evolution and Nucleosynthesis, University of Chicago Press (1983).
[3] Kippenhahn and Weigert, Stellar Structure and Evolution, Springer (1990).
[4] Binney, J. and Tremaine S., Galactic, Dynamics, Princeton University Press (1994).
[5] Binney J, and Merrifield, Galactic Astronomy, Princeton University Press (1998).
[6] K.D. Abhyankar, Astrophysics (Stars and Galaxies), Tata McGraw Hill (1992).
[7] Baidyanath Basu, An Introduction to Astrophysics, Prentice Hall of India (2003).
[8] Jayant V Narlikar, An Introduction to Cosmology, CUP (2004).

PHYS 448 - Mathematical Methods in Physics–II

(4 credits – 60 hours)

Unit-I: Linear Algebra (15 hours)

Introduction to abstract algebra and notation – Definition of groups, real fields, and complex fields Definition of vector space – Vector spaces over an arbitrary field - Linear vector spaces and subspaces – Null space - Span and independence of vector space – Spanning set theorem - Linear dependence and independence – Dimensionality of vector space - Basis sets for finite dimensional and infinite dimensional vector spaces – Linear transformation (mapping) - Norm and Inner product – Unit circles and spheres in inner product spaces - Cauchy-Schwarz Inequality – Orthogonal and orthonormal sets and bases - Completeness – Eigenvalues and Eigenvectors - Matrix representation - Change of orthonormal basis.

Unit-II: Hilbert Spaces and Operators (15 hours)

Definition of metric space and normed spaces – Definition of linear functional – Inner product spaces - Hilbert space – Families of orthogonal polynomials as basis sets in function space (Gram-Schmidt orthogonalization) – Self-adjoint and normal operators – Linear operators – Hermitian, unitary, orthogonal, and projection operators – Trace, inverse, and rank of a linear operator - Rotation matrices in two and three dimensions – Pauli matrices.

Unit-III: Vectors and Tensors in Index Notation (15 hours)

Representation of vectors and matrices in index notation – Einstien summation convention - Dot product, cross product, scalar triple product, and vector triple product using index notation – Vector identities and differential operators in curvilinear coordinates and compact notation using indices – Evaluation of determinant of a matrix using Levi-Civita symbol - Fundamentals of tensors – Cartesian Tensors – Algebra of Cartesian tensors – Outer product – Contraction - Quotient theorem – Symmetric and Skew-symmetric tensors – Kronecker and Levi-Civita tensors – Examples and Applications in physics.

Unit-IV: Group Theory (15 hours)

Introduction to Groups, fields - Definitions and examples of physically important finite groups - Point groups - Multiplication table – Subgroups - Cyclic groups, center, classes, cosets, Lagrange Theorem - Representations of finite groups - Irreducible representation – Characters - Orthogonality theorem - Schur's character table - SU(2) – SU(3) – Simple applications.

Textbooks

[1] V Balakrishnan. Mathematical Physics: Applications and Problems. Springer.
[2] Riley, Hobson, and Bence. *Mathematical Methods for Physics and Engineering*. 2006.
[3] B R Kusse and E A Westwig. *Mathematical Physics*. Wiley, 2010.
[4] Kreyszig. Introductory Functional Analysis with Applications. Wiley, 1978.

Supplementary Readings

[1] Arfken et al., *Mathematical Methods for Physicists*. Elsevier, 2012.
[2] S Hassani. *Mathematical Physics*. Springer International Publishing, 2013.
[3] S Fujita and S V Godoy. *Mathematical Physics*. John Wiley & Sons, 2010.
[4] Byron and Fuller. *Mathematics of Classical and Quantum Physics*. Dover, 2012.

PHYS- 530: Condensed Matter Physics Specialization LAB (2 credits)

1. Powder X-ray diffraction pattern for crystalline material.
2. Infrared spectroscopy for crystalline material.
3. Raman spectrum for crystalline material
4. Impedance spectroscopy study for a crystalline material.
5. UV-VIS spectroscopy for determination of optical band gap.
6. Analysis of M-H loop for a ferromagnetic material.
7. X-ray photoelectron spectroscopy for determination of charge state of metal ions
8. Emission spectroscopy to study optical properties of a semiconductor.
9. Analysis of P-E loop for a ferroelectric material.
10. Study of I-V characteristics of a semiconductor device (Solar cell, LDR, Photo transistor, LED and Photo diode).
11. Study of thermal & electrical conductivity of Copper to measure its Lorentz number.
12. Study of Magnetoresistance in Bismuth and p-Ge crystals.
13. Study of magnetostrictive coefficient of a ferromagnetic metal.
14. To study the dispersion relation for the monoatomic and diatomic lattices. Comparison with theory. Determination of the cut-off frequency of the mono-atomic lattice.

Text Books:
1. Experimental Techniques In Condensed Matter Physics At Low Temperatures by Robert C. Richardson (Editor), Eric N. Smith (Editor), 2019.
2. Springer Handbook of Condensed Matter and Materials by Werner Martienssen (Editor), Hans Warlimont (Editor), 2006.
3. UV/VIS Spectrophotometry Fundamentals and Applications by A. De Caro and Haller Claudia, 2015.
4. A Handbook of Electrical Measurement and Instrumentation bySundar Rajan, Scholars' Press, 2020.
5. Handbook of X-ray Photoelectron Spectroscopy by Joln F Moulder, William F Stickle, Peter E Sobol, and Kenneth D. Bomben, publisher: Perkin-Elmer Corporation (USA), 1992.
6. Experiments in Physics by R. Srinivasan, K. R. Priolkar and T. G. Ramesh (2018)
Supplementary readings:
1. C. Kittel, Introduction to Solid State Physics. John Wiley, Seventh Edition (2003).
2. Eoin P. O'Reilly, Quantum Theory of Solids, Taylor & Francis, First Edition (2002).
3. Ashcroft, Neil W. and Mermin, N. David, Solid State Physics. New York (1976).
4. Dekker A. J. Solid State Physics. MacMillan India Ltd, New Delhi, reprint (1967).
5. J. S. Blakemore, Solid State Physics, Cambridge University Press, 2nd edition (2012).

PHYS 550 ELECTRONICS SPECIALIZATION EXPERIMENTS (3 CREDITS)

1. First order active filters using operational amplifier.
2. Second order active filters using operational amplifier.
3. Counters and registers using logic circuits.
4. Decade counting unit.
5. Study of 8-bit microprocessor.
6. Study of 16 bit microprocessor.
7. Study of 8051 microcontroller.
8. Study of lock-in-amplifier.
9. Amplitude modulation.
10. Detection of AM signals.
11. Study and detection of Frequency modulation.
12. Pulse modulation.
13. Study of multiplexing and demultiplexing.
14. Digital multiplexer.
15. LabVIEW and Virtual instrumentation laboratory.

PHYS 570- LASER SPECIALIZATION EXPERIMENTS (3 CREDITS)

1. Numerical aperture of optical fiber and propagation of light through optical fiber.
2. Intensity profile of laser through optical fiber and determination of refractive index profile.
3. Refractive index by Brewster angle setup.
4. Study of Faraday effect using He-Ne laser with AC modulator.
5. Study of Electro-optic effect (Pockel effect) with AC modulator.
6. Study of Electro-optic effect (Kerr effect).
7. Study of Acousto-Optic effects.
8. Study of Second Harmonic generation
9. Study of Passive Q switching in Nd:YAG laser
10. Study of Active Q Switching in Nd YAG Laser
11. Study of Laser bean characteristics (beam divergence, spot size, intensity profile) using He-Ne laser
12. Estimating Coherence Length of the Given Light Source.
13. Digital holography.
14. Estimation of Stokes Parameter

PHYS 590- ASTROPHYSICS SPECIALIZATION LAB (3 CREDITS)

This course will be done in the Indian Institute of Astrophysics, Bangalore with the faculties of IIA, under the MoU between the Department of Physics and the IIA.

PHYS 531 - QUANTUM MECHANICS-II (4 - 0 - 0 - 4)
(4 credits – 60 hours)

Unit – I (12 hours)
Rotational Symmetry – Infinitesimal and Finite Rotations – Rotation Operator – Rotation Matrices – Scalar, Vector, and Tensor Operators – Reducible and Irreducible Tensors – Irreducible Spherical Tensors – Wigner-Eckart Theorem

Unit – II (12 hours)
Time-dependent perturbation theory – Transition probability – Constant perturbation – Harmonic perturbation – Fermi- Golden rule – Radiative transition in atoms – Dipole transition – Selection rules – Sudden and adiabatic approximation.

Unit – III (12 hours)
Systems of identical particles – Exchange degeneracy – Fermi and Bose particles – the exclusion principle – an ensemble of identical systems – spin-statistics connection – Slater determinant.

Unit – IV (12 hours)
Scattering theory – Scattering particles – Potential scattering – Partial wave analysis – Phase shifts – Scattering lengths–Integral equations in terms of Green function – Born approximation and its validity.

Unit – V (12 hours)
Relativistic wave equations – Klein-Gordon equation – Dirac equation – Dirac matrices – Free Dirac particles – Spin magnetic moment – Spin-Orbit interaction – Central potential – Hydrogen atom – Hole theory and positrons.

Textbooks
[1] N Zettili, Quantum Mechanics: Concepts and applications. John Wiley.
[2] D J Griffiths, Introduction to Quantum Mechanics, Pearson Education.
[3] F Schwable, Quantum Mechanics, Springer.
[4] B H Bransden and C J Joachai, Quantum Mechanics, Pearson India.
[5] J J Sakuri, J Napolitano. Modern Quantum Mechanics, Addison-Wesley

Supplementary Readings
[1] Ashok Das, Lectures on Quantum Mechanics, World Scientific.
[2] Richard L Liboff, Introductory Quantum Mechanics, Pearson Education.
[3] Stephen Gasiorowicz, Quantum Physics, John Wiley & Sons.
[5] Leonard I. Schiff, Quantum Mechanics, McGraw-Hill.

PHYS 532: ATOMIC AND MOLECULAR PHYSICS (4 – 0 – 0 - 4)
(4 credits – 60 hours)

Unit I: 12 hours
Electromagnetic spectrum – Absorption or Emission of radiation – Line width- Natural line broadening Doppler broadening –Pressure broadening – Removal of line broadening - X-ray Spectra – Emission and absorption spectra of X-rays. Regular and irregular doublet laws – X-ray satellites – Photoelectron spectroscopy – Ultraviolet photoelectron spectrometers – XPS techniques and Chemical information from photoelectron spectroscopy – Auger electron spectroscopy.

Unit II: 12 hours
Microwave Spectroscopy: Classification of Molecules -The rotation of Molecule – Rotational spectra of Rigid Diatomic molecule- Isotope Effect in Rotational Spectra- Intensity of Rotational Lines- Non-rigid Rotator Vibrational Excitation Effect- Linear Polyatomic molecules- Symmetric top molecules- Asymmetric top molecules – Stark effect- Quadrupole Hyperfine interaction – Microwave spectrometer – Information derived from Rotational spectra – Infrared Spectroscopy: Vibrational Energy of a Diatomic molecule – The Diatomic Vibrating Rotator – Break down of Born-Oppenheimer Approximation – The Vibrations of Polyatomic molecules – Rotation-Vibration spectra of Polyatomic molecules – Analysis by Infra-red Techniques- I.R. spectrophotometer – Fourier Transform- I.R. spectrophotometer- Applications – Frank-Condon principle and dissociation energy.

Unit III: 12 hours
Raman Spectroscopy: Theories of Raman scattering – Rotational Raman Spectra – Vibrational Raman Spectra – Mutual Exclusion principle – Raman Spectrometer – Polarisation of Raman Scattered light – Structural determination from Raman and I.R. spectroscopy - Near IR FT-Raman spectroscopy.

Unit IV: 12 hours
Nuclear Magnetic Resonance Spectroscopy: Basic principles – magnetic resonance – relaxation processes – pulsed (Fourier Transform) NMR – wide line NMR spectrometers – Spectra and molecular structure – chemical shifts – spin-spin coupling – integration – applications – Electron Spin Resonance Spectroscopy: Basic principles – ESR spectrometer – ESR spectra – Hyperfine interaction – g-factor – line widths – applications.

Unit V: 12 hours
NQR and Mossbauer Spectroscopy: Quadrupole Hamiltonian- Nuclear Quadrupole energy level for axial and non-axial symmetry – Experimental techniques and applications – Mossbauer Spectroscopy: Principles of Mossbauer spectroscopy – Chemical shifts – Quadrupole splitting and Zeeman splitting – applications of Mossbauer spectroscopy – applications.

Textbooks

[1] H. E. White, Introduction to Atomic Spectra. McGraw Hill.
[2] B. P. Straughan and S. Walker, Spectroscopy Vol. I, II, III.
[3] Banwell and McCash, Fundamentals of Molecular Spectroscopy, McGraw Hill.
[4] G.Aruldhas, Molecular Structure, and Spectroscopy, Prentice-Hall.
[5] S L Gupta, V Kumar, and R C Sharma, Elements of Spectroscopy (Atomic, Molecular and Laser Spectroscopy). Pragati Prakashan, Meerut.

Supplementary Readings

[1] D. A. Long, Raman Spectroscopy.
[2] Tores and Schawlow, Microwave Spectroscopy. McGraw Hill.
[3] Schneider and Berstin, High-Resolution NMR. McGraw Hill.
[4] Assenheim, Introduction to ESR. Plenum Press.
[5] Das and Hahn, Nuclear Quadrupole Resonance Spectroscopy. Academic Press.
[6] Goldanskil, Mossbauer effect and its application to Chemistry. Von Nestrand.

PHYS 533: CONDENSED MATTER PHYSICS (3 credits)

Unit I: Liquid State: [12 hours]

Classification of liquids (ionic, molecular and simple) and interactions in liquids– idea of attractive and repulsive potentials -stability condition of bond -Hydrogen molecule –neon liquid - Lenard Jones potential in liquid- theory of scattering in neon liquid - radial distribution function - structural determinations.

Unit II: Equilibrium Structure of Dense Fluids: [12 hours]

Molecular distribution – Van der Waals equation – liquid in canonical ensemble- second virial term – general virial approach thermodynamic functions in dense fluids – equation for pair distribution functions Kirkwood superposition approximation – critical phenomena: critical properties of Van der Waals fluid.

Unit III: Liquid Crystals & Optical properties: [12 hours]

Classification of liquid crystals and mesoscopic phase transitions (nematic, semetic, cholestric) – Landau theory phase transition and Marier Saupe theory in liquid – Optical reflectance: Kramers-Kronig relations, Raman effect in liquids & crystals - Plasmons

Unit IV: Dielectrics & Ferroelectrics: [12 hours]

Macroscopic electric field, local electric field at an atom, Dielectric constant and Polarizability, structural phase transitions, ferroelectricity , Displacive transitions, Relation of dielectric constant and polarization – dipolar polarization theory – time dependence of polarization temperature dependence of dipolar polarization, electrical conductivity (D.C & A.C).

Unit V: Surface, Interface Physics & Nanostructured Materials: [12 hours]

Surface & Interface Physics: Surface crystallography, Surface electronic structure, Magnetoresistance in a two-dimensional channel, heterostructures, tunneling magnetoresistance, scanning tunneling microscopy.

Nanostructured Materials: Synthesis of Nanomaterials by different methods, Size and Shape dependent Structural, Chemical, Optical, Electrical and Mechanical Properties, Nanoindentor, Atomic Force Microscopy.

Text books:

1. Introduction to Liquid State Physics C. A. Croxton John Wiley and Sons, 1975
2. Atkin's Physical Chemistry Peter Atkins and Juliode Paula Oxford University
3. N. W. Aschcroft and N. D. Mermin, Solid state physics, Holt, Rineheart and Winston, New York (1976)
4. C. Kittel, Introduction to solid state physics. John Wiley (2003) Seventh Edition.
5. A. J. Dekker, Solid state physics, MacMillan (1981).

References:

1. Principles of Condensed Matter Physics. P.M.Chaikin and T.C.Lubensky, Cambridge University Press 1997.
2. Liquid Crystals S. Chandrasekar Academic Press 1996

PHYS 534: ADVANCED ELECTRONIC DEVICES AND CIRCUITS **(3 credits)**

Unit I: Advanced Electronic Devices **8 hours**

Advanced Electronic Devices: Schottky diodes, MOSFET, IGBT, Thyristors, Diac, Triac, Charge-coupled devices – Structure and working, V-I characteristics and applications.

Unit II: Other Electronic Devices **8 hours**

Other Electronic Devices: Electro-optic, magneto-optic, Acousto-optic, Piezo-electric, Electro-strictive, magneto-strictive effects, related material properties for these effects – application in sensor and actuator devices.

Unit III: Programmable devices **10 hours**

Programmable devices: PAL, PLA, PLD, CPLD and FPGA – Structure and working, comparison with standard logic devices and application – Memories – Classification of memories, Static and dynamic shift register ROM, PROM, EPROM – Principle and operations, Read/write memories – SRAM, DRAM, DDRAM – Principle and operations – recent advancement in solid-state memories.

Unit IV: Data conversion circuits **10 hours**

Data conversion circuits: Digital to Analog conversion – Weighted and R-2R ladder networks, Frequency to Voltage converters, Analog – to – Digital conversion methods – integrating – single and dual slope converters, Successive approximation, Voltage to frequency and flash converters – Principle, operation and applications.

UNIT – V: Data acquisition and Virtual Instrumentation **10 hours**

Introduction to RS232, RS485 – Basics of Interfacing – IEEE 488.2 standards and GPIB – Introduction to USB, PCMCIA, VXI, SCXI, PXI – Historical Perspective and advantages of Virtual Instrumentation (VI) – Defining VI – Block Diagram & architecture of VI – Data Flow Techniques – Graphical Programming in Data Flow – Comparison with conventional programming – Introduction to LabVIEW.

Text Books

1. *Semiconductor Physics and Devices: Basic Principals, by Donald A Neamen 3rd Edition* (TMH)
2. *Solid State Electronic Devices by Ben G Streetmann and Sanjay K Banerjee, 5th Edition Pearson Prentice-Hall*
3. *Digital Design : Principal and Principal and Practices by Wakerly J. F, 3rd Edition, Prentice Hall's*
4. Ramesh S. Goanker, Microprocessor architecture, programming and applications with 8085/8085A. Wiley Eastern.
5. *Analog Integrated Circuit Design by David A. Johns and Ken Martin, John and Wiley 2008.*
6. Bruce Mihura (2001). LabVIEW for Data Acquisition. Prentice Hall.

PHYS 535: LASER THEORY (3 – 0 – 0 - 3)
(3 credits - 45 hours)

Unit: I Brief Review 11 hours
Maxwell's equations; Wave equations, Origin of refractive index; Coherence; Quantum theory of Atomic energy levels and selection rules for single electro and multi-electron atoms.

Unit: II Radiative Transition 11 hours
Decay of excited states, Emission broadening and line width due to radiative decay, Different broadening mechanism of emission spectra, Radiation laws- cavity radiation, absorption and stimulated emission- Einstein's A and B Coefficient.

Unit: III Introduction To Lasers 12 hours
Condition for producing a laser – population inversion, gain and gain saturation; Saturation intensity, the threshold requirement for a laser, laser oscillation above a threshold. Requirements for obtaining population inversion- 2, 3, and 4 level systems; Steady state and transient population process which destroy population Inversion.

Unit: IV Laser Pumping 11 hours
Excitation threshold requirement, pumping pathway - Specific excitation parameters associated with optical and particle pumping.

Unit: V Laser Resonators 11 hours
Laser cavity modes - longitudinal and transverse cavity modes. Properties of laser modes – Mode characteristics and effect of modes in gain profile, Stable laser resonators, and propagation of Gaussian beams using ABCD matrices.

Textbooks

[1] William T. Silfvast, Laser Fundamentals.
[2] Peter W Milonni and Joseph H. Eberly, Lasers.
[3] Amnon Yariv, Quantum Electronics.

PHYS 536 - Nonlinear Optics and Materials (3 – 0 – 0 - 3)
(3 credits – 45 hours)

Unit I: 9 hours

Maxwell Equations, Wave Equations in various media and its propagation (Brief Survey)- Origin of Complex Refractive Index - Classical theory of Optical Absorption (Electron Oscillator Model) and Dispersion (Lorentz Oscillator Model)- Classical theory of anharmonic oscillators.

Unit II: 9 hours

Wave equations description of nonlinear optical susceptibilities – Symmetries in Nonlinear Optical systems- Frequency and intensity dependence of polarization and dielectric susceptibility-First order and higher order susceptibilities

Unit III: 9 hours

Second order optical nonlinearities Second harmonic generation –sum and difference frequency generation, parametric processes – Simple theory and calculation of nonlinear polarization –Various phase matching techniques in SHG

Unit IV: 9 hours

Third order optical nonlinearities - Third harmonic generation, four-wave mixing, Kerr Nonlinearity, Intensity dependent effect, Self-Phase modulation, Cross phase modulation Stimulated Raman Scattering (SRS), Stimulated Brillouin Scattering, Parametric gain – Parametric amplification and oscillation.

Unit-V 9 hours

Optical bistability, Optical Phase Conjugation Theory and Applications, Electro-Optic Effect (Pockel and Kerr Effect), Photorefractive effect and applications, Solitons Theory and applications.

Textbooks

[1] Robert W Boyd, Nonlinear Optics.
[2] Y Guo, C K Kao, E.H.Li, K. S.Chiang, Nonlinear Photonics.
[3] Y R Shen, Principles of Nonlinear Optics.
[4] N. Bloembergen, Nonlinear Optics.
[5] H S Nalwa and S Miyata, Nonlinear Optics of Organic Molecules and Polymers.
[6] RA Fischer, Optical Phase Conjugation.
[7] Quantum Electronics–A Yariv
[8] R Sutherland, Handbook of Nonlinear Optics.
[9] N B Singh, Growth and Characterization of Nonlinear Optical Materials.

PHYS 537: EXPERIMENTAL DESIGN (3 – 0 – 0 - 3)
(3 credits – 45 hours)

UNIT – I: 11 hours
Measurement of fundamental constants: e, h, c – Measurement of high and low resistances, inductance, and capacitance – Detection of X-rays, Gamma rays, charged particles, neutrons – Ionization chamber – Proportional counter – GM counter – Scintillation detectors – Solid State detectors –

UNIT – II: 11 hours
Emission and Absorption Spectroscopy – Measurement of Magnetic field – Hall effect – Magnetoresistance – X-ray and neutron Diffraction.

UNIT – III: 11 hours
Vacuum Techniques – The basic idea of conductance, pumping speed – Pumps: Mechanical Pump – Diffusion pump– Gauges – Thermocouple gauge – Penning gauge – Pirani gauge – Hot Cathode gauge – Low-temperature systems – Cooling a sample over a range up to 4 K – Measurement of low temperatures.

UNIT – IV: 12 hours
Measurement of energy and time using electronic signals from the detectors and associated instrumentation – Signal processing – A/D conversion – multichannel analyzers – Time-of-flight technique – Coincidence Measurements – true to chance ratio – Correlation studies. Error Analysis and Hypothesis testing – Propagation of errors – Plotting of Graph – Distributions – Least squares fitting – Criteria for the goodness of fits – Chi-square test.

Textbooks

[1] J.P. Holman, Experimental Methods for Engineers. 7th Edition. McGraw Hill (2000).
[2] J. M. Lafferty (Editor) (1998), Foundations of Vacuum Science and Technology, Wiley Interscience.
[3] Anthony Kent, Experimental Low-Temperature Physics, Macmillan Physical Science (1993).
[4] Douglas C. Montgomery, Design and Analysis of Experiments, John Wiley(2004).

Supplementary reading

[1] T. G. Beckwith, R. D. Marangoni, and J. H. Lienhard, Mechanical Measurements, 6th Edition(2006), Prentice Hall.
[2] Ernest O Doebelin, Measurement Systems: Application and Design. Tata McGraw Hill.
[3] Albert D Helfrick and William D Cooper (1992), Modern Electronic Instrumentation and Measurement Techniques. Prentice Hall.
[4] Hermann K P Neubert, Instrument Transducers: An introduction to their performance and design. Oxford University Press(2003).
[5] J. A. Blackburn Modern Instrumentation for Scientists and Engineers, Springer (2001),

PHYS 539 PLASMA PHYSICS AND CONTROLLED FUSION **3 credits**

(45 hours per semester+15 Experimental Demonstration)

UNIT – 1 Collision processes in gases discharge mechanism **(10)**

Breakdown mechanism of gases, Gaseous discharge, Characteristic of dc Glow discharge, positive column, cathode sheath, negative glow, negative glow and Faraday dark space, Analysis of positive column, Analysis of cathode region.

UNIT –2 Plasma and Plasma Parameters **(10)**

Definition of plasma, electron and ion temperature, plasma potential, sheath formation and floating substrate, Debye shielding, The Contact Potential, sheath formation and Bohm criterion, cathode sheath, Plasma oscillations, electron oscillations ion oscillation, Ambipolar diffusion.

UNIT – 3 Plasma sources and Applications **(10)**

Limitations of dc glow discharges, RF discharges, Inductive discharges, power transfer efficiency, matching network, electron-cyclotron resonance discharges, helicon-discharges, surface wave discharges, DBD discharges, characteristics and application of respective discharges, hollow cathode discharge, planer magnetron discharge, plasma etching, dc sputtering, rf sputtering, thin film formation, plasma nitriding, PECVD for nano - material fabrication.

UNIT – 4 Plasma For Controlled Fusion **(15)**

Fission, Fusion and energy needs, Lawson criterion, Magnetic confinement fusion devices (magnetic mirrors trap, tokomak), Particle trajectories in non-uniforms magnetic and electric fields. Drift approximation. Adiabatic invariants. Plasma as a fluid, plasma heating, Current drive, low hybrid current drive (LHCD), Ion Cyclotron Resonance Heating (ICRH), Ion Cyclotron Resonance Heating (ECRH), Neutral beam injection (NBI). Laser and heavy ion beams fusion, Tokomaks in India and ITER and challenges

UNIT-5 Experimental Demonstration **(15)**

1. Dependence of breakdown voltage on pressure and electrode gap (Paschen Curve).
2. Measurement of Plasma parameters by electrostatic probe (Langmuir Prob).
3. To measure the plasma parameters by double Langmuir probe
4. To launch an ion-acoustic wave and demonstrate collective behavior of the plasma
5. Measurement of plasma parameters of a pulsed dc discharges
6. Characterization of dc magnetron discharges and estimation of sputtering yield
7. Studying the conditions for atmospheric pressure plasmas (Dielectric Barrier Discharges)

Text Books

1. Chapman, Brian N. “Glow discharge processes” A Wiley-Interscience Publications
2. M. A. Lieberman and A. J. Lichtenberg, Principles of Plasma Discharges and Material Processing, John Wiley & Sons, New Jersey, 2005.
3. Y. P. Raizer, “Gas Discharge Physics”, Springer 1991.

Reference Books

1. P. I. John, Plasma Science and the Creation of Wealth, Tata McGrow-Hills, New Delhi, 2005.
2. F.F. Chen, “Plasma Physics and Controlled Fusion”, Plenum Press, New York, 1984

PHYS 551 – STATISTICAL PHYSICS (4 – 0 – 0 - 4)
(4 credits – 60 hours)

Unit I: Foundations 12 hours
Microstate and Macrostate of macroscopic system, Phase space and Phase space density, Liouville theorem, Ergodic hypothesis, Postulate of Equal a priori probabilities, Microcanonical Ensemble, Number of microstates and relation to thermodynamic entropy, Calculation of the number of microstates to (a) Ideal gas: Equation of state, Gibbs paradox, correct counting (b) Crystalline solid: Dulong Petit's law, Einstein's theory of specific heat and (c) Paramagnetism: Curie's law, Negative temperature, and Schottky anomaly in specific heat (d) Elasticity of a rubber.

Unit II: Canonical Ensemble 12 hours
Canonical ensemble canonical partition function - The Darwin Fowler method, Calculation of thermodynamic properties from partition function, Equipartition theorem and Virial theorem - Application of canonical partition function to (a) Ideal gas (b) Crystalline solid (c) Black body radiation: Planck's theory (d) Theory of paramagnetism: Langevin and Brillouin functions (e) Diatomic molecular gas.

Unit III: Grand Canonical Ensemble 10 hours
The chemical potential, Grand canonical ensemble, and grand partition function, Fugacity, Relation of the grand partition function to thermodynamics, Application to (a) Adsorption desorption process, (b) Chemical reactions

Unit IV: Quantum Statistics 14 hours
Density operator, Spin statistics connection, Grand partition function for ideal Bose and Fermi gases, Bose-Einstein, Fermi-Dirac, and Maxwell-Boltzmann distributions, Application to (a) Electrons in metals (b) Pauli paramagnetism (c) Landau diamagnetism (d) Theory of White dwarf stars (e) Black body radiation: Bose theory (f) Debye theory of specific heat (g) Bose-Einstein condensation.

Unit V: Phase Transitions 12 hours
Phase transitions, Order of transition, Order parameter, Critical phenomena, and critical exponents, Scaling theory and Universality class, Correlation function and fluctuation-dissipation theorem, Landau theory of phase transition, Ising Model, Brag Williams theory, Random walk and diffusion equation, Brownian motion,

Textbooks
[1] K. Huang, Statistical Mechanics, John Wiley & Sons (1987) Second Edition.
[2] R. K. Pathria, Statistical Mechanics, Butterworth-Heinemann (1996) Second Edition
[3] L. E. Reichl, A Modern Course in Statistical Physics, John Wiely (1998).

Supplementary Readings
[1] F. Reif, Statistical Physics. McGraw Hill (1967).
[2] R.P. Feynman, Statistical Mechanics, Benjamin Cummings Inc. (1972)
[3] E. S. R. Gopal, Statistical Mechanics. MacMillan India (1988).
[4] F. Mandl, Statistical Physics, John Wiley (1988) Second Edition.
[5] D. Chandler, Introduction to Statistical Physics, Oxford University Press (1987).
[6] R. Kubo, Statistical Mechanics, North-Holland (1965).
[7] D. Yoshioka, Statistical Mechanics, Springer-Verlag (2007)
[8] L. D. Landau and E. M. Lifshitz, Statistical Physics, Addison-Wesley (1969).
[9] I. Prigogine, Order out of chaos, Fontana (1984).
[10] C. Kittel, Elementary Statistical Physics, John Wiley (1958).

PHYS 541 - NUCLEAR PHYSICS (4 - 0 - 0 – 4)
(4 credits – 60 hours)

Unit – I 12 hours

Nuclear Properties and Nuclear Forces: Introductory ideas about nuclear forces and range - Deuteron problem - n-p and p-p scattering at low energy - electric quadrupole moment of Deuteron - Introductory idea about Bartlet, Majorana, Heisenberg exchange forces – Concept of Isotopic spin – Yukawa meson theory.

Unit – II 12 hours

Nuclear Models: Gas model - Liquid drop model - Semi-empirical mass formula - Magic numbers - Shell model -magnetic moment and electric quadrupole moment - Collective model.

Unit – III 12 hours

Nuclear Decay: Stability of nuclei - Radioactive decay laws - Gamow's theory of alpha decay - Beta decay - Fermi's theory - Conservation of parity - Weak interactions - Pair production – Internal conversion - Gamma decay - Selection rules.

Unit – IV 12 hours

Nuclear Reactions: Conservation laws - Q value - Compound nuclei and direct reactions Nuclear fission reaction - Fissionability parameter (theory of fission) - Controlled fission reactor - Nuclear fusion - Thermo nuclear reactions.

Unit – V 12 hours

Elementary Particles: Classification - Symmetries and symmetry violations - Quantum numbers (like charge, spin, parity, isospin, strangeness, etc.) - Gellmann- Nishijima formula - Properties and decay models of Baryons, Mesons, Hadrons - Tau-Theta Puzzle - Introductory about quark model and GUT idea.

Textbooks

[1] Kenneth S. Krane, Introductory nuclear physics, Wiley, 2016.
[2] Irving Kaplan, Nuclear Physics, Narosa, 2002.
[3] Ashik Das, Introductory nuclear and particle physics, John Wiley, 1993.
[4] R. R. Roy, Nuclear Physics-Theory and Experiments, New Age, 2014.
[5] Dodd and Gripaios, Idea of Particle Physics, Cambridge University Press, 2020.

Supplementary Readings

[1] L. Cohen, Concepts of Nuclear Physics, Tata McGraw Hill, 1998.
[2] Palash B. Pal, An Introductory Course of Particle Physics, 2014.
[3] S. L. Kakani and S. Kakani, Nuclear and Particle physics, Viva, 2013.
[4] I. S. Hughes, Elementary Particles, Cambridge University Press, 2012.
[5] H. A. Bethe and D. Morrison, Elementary Nuclear Theory, Dover, 2016.

PHY 542 - LASER SYSTEMS (3 – 0 – 0 - 3)
(3 credits - 45 hours)

Unit I: Special Laser Cavities and Cavity Effects 9 hours
Unstable resonator, Q-switching, Mode locking, Different Methods, Ring laser, Cavities for producing spectral narrowing of laser output, laser cavities requiring small diameter gain region astigmatically compensated cavities.

Unit II: Specific Laser System – I 9 hours
He -Ne laser, Argon ion laser, Helium Cadmium laser, Copper vapor laser, Carbon dioxide laser, Nitrogen laser, Far Infrared gas laser.

Unit III: Specific Laser System – II 9 hours
Dye lasers, Ruby laser, Nd-YAG laser, Alexandrite laser, Ti-Sapphire laser, Color center laser, Semiconductor lasers.

Unit IV: Specific Laser System – III 9 hours
Chemical laser, X-ray Laser, Free electron laser, Excimer laser, Fiber laser.

Unit V: Ultra Short Pulse Laser 9 hours
Concept of measuring brief intervals of time Pico seconds and femtosecond Techniques. Method of generating pulses optical pulse properties and methods of measurement of pico and femtosecond pulses.

Textbooks

[1] W T Silfvast, Laser Fundamentals, Cambridge University Press.
[2] P W Milonni and Joseph H. Eberly Lasers.
[3] C Rulliere, Femto second laser pulses, Springer.
[4] S.L. Shapiro, Ultrashort light pulses: Picosecond techniques and applications.

PHYS 543: PHYSICS OF AMORPHOUS AND CRYSTALLINE SOLIDS **(3 credits)**

UNIT I: Synthesis and Characterization Techniques: [12 hours]

Solid state and wet chemical methods for preparation of polycrystalline and amorphous materials – Thin film techniques; thermal evaporation, RF sputtering, Pulsed laser deposition (PLD) - Structure: Comparison of X-ray and Neutron diffraction, Raman-Thermal analysis; TG, DTA, DSC- IR, SEM, ESCA, AES & TEM with EDAX

UNIT II: Defects and Dislocations: [12 hours]

Crystal growth, Thermodynamics of point defects, Schottky and Frenkel defects, color centers, polarons & excitons, Dislocations, Strength of crystals, crystal growth, stacking faults & Grain boundaries.

UNIT III: Alloys & Diffusion Process in Crystals: [12 hours]

Alloys: Substitutional solid solutions – Hume –Rothery Rules, Order-Disorder Transformation, Phase diagrams, Transition Metal Alloys, Kondo effect

Phenomenological aspects of diffusion- Microscopic aspects of diffusion – Measurement of diffusion coefficients. Electron conduction in solids: Measurement of conductivity – Determination of transference numbers – Interrelation among diffusion coefficient, mobility and ionic conductivity.

Unit IV: Microscopic Structure and Atomic Transport [12 hours]

X-ray absorption spectroscopy – magnetic resonance – structural modeling: Dense random packing – continuous random packing – Theory of ionic conductivity – ionic conductivity in crystalline solids and amorphous solids – electrode polarization – solid electrolyte and fast ion conductors – criterion for fast ion conductors – frequency dependence transport.

Unit V: Ionic Solids: [12 hours]

Fast Ionic materials; alkali metal ion conductors- β alumina's-Silver ion conductors, - Cation conductors – Oxygen ion conductors – Halide ion conductors – Proton conductors

Text books:

1. Principles of Electronic Ceramics, L. L. Hench and J. K. West, (JohnWiley& Sons, New York), 1990.
2. T.Kudo and K.Fueki, Solid State Ionics (VCH,Tokyo, Japan)1990.
3. A.R. West, Solid State Chemistry, (John wiley& Sons)1984.
4. S. Chandra, Superionic Solids, North-Holland, Amsterdam, 1981.
5. S.O.Pillai, Solid State Physics Structure and Electron related properties(Wiley Eastern Limited, New Delhi) 1994.
6. Azaroff; Introduction to Solids (TMH, New Delhi)

References:

1.H.P.Myers; Introductory Solid State Physics (Viva. New Delhi) 1998.
2.B. V. R. Chowdari, M. A. Careem, M A K L Dissanayake, R M G Rajapakse, V A Seneviratne, "Solid State Ionics: Advanced Materials for Emerging Technologies, (World Scientific Publishing Company) 2006.
3.T. Minami, M. Tatsumisago, M. Wakihara, C. Iwakura, "Solid State Ionics for Batteries" (Springer) 2005.
4.J. Ross Macdonald, Impedance Spectroscopy: emphasizing solid materials and systems, (John Wiley & Sons) 1987.

PHYS: 544 – Magnetism and Magneto-Transport Phenomena (4 – 0 – 0 - 4)
(4 credits – 60 hours)

Unit I: Theories of Magnetism: [15 hours]
The exchange interaction: direct and indirect interaction, double exchange, anisotropic exchange interaction, the Bethe-Peierls- Weiss method, Band theories of ferromagnetism, Neel's theory of ferrimagnetism, Crystalline anisotropy, Spin wave theory.

Unit II: Thermal Relaxation and Resonance [15 hours]
The magnetocaloric effect, Paramagnetic relaxation: Spin-lattice relaxation, spin-spin relaxation, Paramagnetic resonance: Line widths, fine and Hyperfine structure, the spectra of the transition Group ions, the spectra of Paramagnetic Molecules and other systems.

Unit III: Magneto-transport [15 hours]
Basic electron transport and Boltzmann transport equation, Phenomenological theory of giant magnetoresistance (GMR), colossal magnetoresistance (CMR), Anisotropic magnetoresistance (AMR), magneto transport in Semiconductors, Quantum Hall effect.

Unit IV: Advanced Magnetic properties: [15 hours]
De Haas-van Alphen effect, Cyclotron, Critical phenomena in magnetic materials, Magnetoelasticity, Multiferroics, Nanoparticle magnetism- core-shell model, Super paramagnetism.

Textbooks

[1] The Physical Principles of Magnetism by A H Morrish, R E Krieger Publishing Company (1980).
[2] A J Dekker, Solid state physics, McMillan (1981).
[3] B D. Cullity, Introduction to Magnetic Materials. Wiley.
[4] D Jiles, Introduction to Magnetism and Magnetic Materials. Chapman and Hall.

Suggested Readings

[1] Physics of Magnetism and Magnetic materials by K.H.J. Buschow and F R DeBoer
[2] Spin electronics, - Edited by M.J. Thornton, M. Ziese, Springer 1st edition (2000).
[3] J. M. D. Coey, Magnetism, and Magnetic Materials, Cambridge University Press.
[4] R.C.O. Handley, Modern Magnetic Materials, Wiley.
[5] Stephen Blundell, Magnetism in Condensed Matter Physics, Oxford University Press.
[6] Nicole A. Spaldin, Magnetic materials: fundamentals and device applications.

PHYS 545 - SIGNAL PROCESSING AND COMMUNICATION (4 – 0 – 0 - 4)

(4 credits - 60 hours)

Unit I: Signals and Sampling 10 hours

Signals, classification of signals, basic operation on signals, elementary signals, systems, properties of systems, Sampling continuous-time signals, sampling a sinusoid, aliasing, sub-sampling, sampling theorem, ideal reconstruction, and practical reconstruction: zero-order hold.

Unit II: Fourier Representation 13 hours

Fourier representation for four classes of signals, discrete-time periodic signals, discrete-time Fourier series, continuous-time periodic signals and the Fourier series, discrete-time non-periodic signals, and the discrete-time Fourier transform, continuous-time nonperiodic signals and the Fourier transform. Parseval relationship, Time-Bandwidth product, Duality.

Unit III Communications Systems 10 hours

Basic information theory; Modulation and detection in analog and digital systems; Sampling and data reconstructions; Quantization and coding; Time division and frequency division multiplexing; Equalization; Optical Communication: in free space & fiber optic; Propagation of signals at HF, VHF, UHF and microwave frequency; Satellite Communication.

Unit IV Microwave communications 12 hours

Microwave Tubes and solid state devices, Microwave generation and amplifiers, Waveguides and other Microwave Components and Circuits, Microstrip circuits, Microwave Antennas, Microwave Measurements, Masers, lasers; Microwave propagation. Microwave Communication Systems terrestrial and Satellite based.

Textbooks:

[1] S.Haykin and B.Van Veen, Signals and Systems (II edition); Wiley Student Edition.
[2] B.P.Lathi, Signal processing, and linear systems; Oxford University Press, 2003.
[3] P.N.Denbigh, System analysis, and signal processing; Addison Wesley, 1998.
[4] S.P.Eugene, Signals, systems, and signal processing; Xavier.
[5] Samuel Y. Liao, Microwave Devices and Circuits; Pearson Education, 3rd Edition, 2003.
[6] 6. Annapurna Das, Sik. Das, Microwave Engineering; Tata McGraw-Hill, 2009.
[7] 7. Kennedy Davis, Electronic Communication Systems; Tata Mc Graw-Hill, 2008.
[8] 8. Simon Haykin, Communication Systems, 3rd Edition, Wiley India Edition, 2008.

PHYS 546 – ELECTRONIC MEASUREMENT TECHNIQUES AND ANALYSIS
(3 – 0 – 0 - 3) (3 credits - 45 hours)

UNIT – I: 12 hours
Measurement Basics: Significance of measurement – Role of instruments in industrial processes – Block representation of measurement systems – Need for calibration and standards – Instrument parameters: sensitivity, accuracy, resolution, span, range – Classification of instruments – Generalized system configuration - Functions and characteristics of instruments and measurement systems – Errors in measurement – Analysis, sources of errors and techniques for error-minimizing.

UNIT – II 11 hours
Transducers: Classification of instrument transducers – Input and output characteristics – Static and dynamic response – Linearity and hysteresis. Examples of (i) resistive, (ii) inductive, (iii) capacitive, (iv) thermoelectric, (v) photo-electric, (vi) piezo-electric, (vii) ionization, and (viii) Hall-effect based transducers – Displacement measurement – Force and torque measurement – Pressure and sound measurement – Relationship between absolute, atmospheric and gauge pressures – Fluid flow measurement – Temperature measurement – Measurement of light – Measurement of the magnetic field.

UNIT III: 11 hours
Network Theory: Network analysis techniques; Network theorems, transient response, steady state sinusoidal response; Network graphs and their applications in network analysis; Tellegen's theorem. Two port networks; Z, Y, h, and transmission parameters. Combination of two ports, analysis of common two ports.

UNIT IV: 11 hours
Network Functions: parts of network functions, obtaining a network function from a given part. Transmission criteria: delay and rise time, Elmore's and other definitions effect of cascading. Elements of network synthesis.

Text Books:
1. Van Valkenburg, Network Analysis; 3rd edition, Prentice-Hall, 1974.
2. A. Sudhakar, Shyammohan S. Palli, Circuits and Networks. Tata Mc Graw Hill, 2010.
3. Beckwith, Marangoni, Lienhard (2006) Mechanical Measurements, Prentice Hall.

Reference Books:
[1] Ernest O Doebelin. Measurement Systems. Tata Mc Graw Hill.
[2] Helfrick and Cooper. Modern Electronic Instrumentation and Measurement Techniques. Prentice Hall, New Delhi, 1992.
[3] Hermann K P Neubert. Instrument Transducers. Oxford University Press, 2003

PHYS 547: VISUAL PROGRAGRAMMING (Pre-requisite: PHYS-436) (3 credits)

UNIT – I: 10 hours

Review of C++ programming – C++ streams – Console streams – Console stream classes-formatted and unformatted console I/O operations, manipulators – File streams – File pointers and manipulations of file I/O – Exception handling – Object-oriented paradigm – Elements of object oriented programming – Merits and demerits of OO (object oriented) methodology – Classes and objects – constructors and destructors – Operator overloading – Data encapsulation – Member functions – Inheritance – Virtual functions – Polymorphism.

UNIT – II: 10 hours

Review of procedure oriented programming – Introduction to events – Event handling principles – GUI concepts – Overview of Windows programming – Creating the window – Displaying the window – message Loop – windows procedure – painting and repainting – WM_PAINT message – WM_DESTROY message – An Introduction to GDI – Child window control.

UNIT – III: 10 hours

Visual Basic Programming: IDE – Introduction to Forms – Intrinsic Controls –Working with files – Accessing databases with data control – Classes and Objects – ADO Object Model – Using Windows Common dialogs – Introduction to dynamic link library.

UNIT – IV: 10 hours

Visual C++ Programming: Windows Programming Model – Visual C++ components – Microsoft foundation classes Library (MFC) – Application Framework – Using AppWizard – Basic Event handling – Graphics Device Interface, Colors and fonts – Modal and Modeless Dialogs – Windows common dialogs – Windows Message Processing and Multithreading.

UNIT – V: Laboratory Exercise Session 8 hours

The laboratory sessions involve exercise on the following: Creation of files and file handling – Classes with primitive data members – Classes with arrays as data members – Classes with pointers as data members – String Class – Classes with constant data members – Classes with static member functions – Operator Overloading – Function Overloading – Writing code for keyboard and mouse events – Creating Dialog Based applications – Creating SDI and MDI applications.

Textbooks

1. Charles Petzold (1996). *Windows Programming*, Microsoft press(Units-I, II).
2. Francesco Balena (2001). *Programming Microsoft Visual Basic 6.0.* Microsoft press(Unit-III) .
3. David Kruglirski (1998). *Programming Microsoft Visual C++ 6.0.* Microsoft press(Unit-IV).

PHYS 548 QUANTUM ENTANGLEMENT **(3 credits)**

Unit I: **12 Hrs**

Postulates of Quantum Mechanics. Dirac formalism, EPR paradox; hidden variable & Bell's theorem; Quantum calculation of the correlation in Bell's theorem; Bell's theorem without inequalities (GHZ equality).

Unit II: **12 Hrs**

Entanglement as physical resource, Quantum circuits; Quantum search algorithm, Quantum Computers-Physical realization, Condition for quantum computation, Different implementation schemes for quantum computation

Unit III: **12 Hrs**

Quantum information theory (Distinguishing Quantum states, Data compression, Classical & Quantum information & noisy Quantum channels), Quantum Cryptography (Bennett- Brossard protocol)

Unit IV: **8 Hrs**

Quantum Non demolition measurement Quantum key distribution and security of quantum key distribution.

Book:

1. M A Nielsen & I L Chuang, Quantum Computation & Quantum Information Cambridge, 2001.
2. Mikio Nakahara and T Ohmi, C Quantum Computing, RC Press (2007).

PHYS 549 LASER SPECTROSCOPY **(3 credits)**
(For Post-graduate students as a soft-course)

Chapter-I : Laser as Spectroscopic Light Sources **6 Hrs.**
Fundamental of Lasers-Laser Resonators-Spectral Characeteristics of Laser Emission- Experimental Realization of Single Mode Lasers- Controlled Wavelength Tuning of Single Mode Lasers- Linewidths of Single Mode Lasers.

Chapter-II : Nonlinear Optical Mixing Techniques & Spectroscopy **10 Hrs.**
Physical Background- Phase matching-Second Harmonic Generation- Quasi Phase Matching- Sum Frequency and Higher- Harmonic Generation- Difference Frequency Spectrometer.

Chapter-III : Absorption and Fluorescence Spectroscopy with Lasers **10 Hrs.**
Advantages of Lasers in Spectroscopy – Direct Determination of Absorbed Photons – Ionization Spectroscopy-Optogalvanic Spectroscopy- Laser Induced Fluorescence- Comparison between the Different Methods .

Chapter-IV : Nonlinear Spectroscopy **10 Hrs.**
Linear and Nonlinear Absorption- Saturation of Inhomogeneous Line Profiles-Saturation Spectroscopy-Polarization Spectroscopy-Multiphoton Spectroscopy-Special Techniques of Nonlinear Spectroscopy

Chapter-V: Time Resolved Spectroscopy **9 Hrs.**
Lifetime Measurements with Ultra fast Laser pulses-Pump-and –Probe Techniques.

Text Book:

W. Demtroder, Laser Spectroscopy –Basic Concepts and Instrumentation Springer, New York, Third Edition (ISBN 81-8128-205-1

PHYS 552 – ASTROPHYSICS-I (3 credits - 45 hours)

Unit – I: Celestial coordinates (9 hours)
Co-ordinate system, Time System-Solar and Sidereal times, Spherical trigonometry, Magnitude scale - Apparent and Absolute magnitudes, Trigonometric Parallax.

Unit – II: Astronomy in different bands (9 hours)
Resolving power of a telescope, atmospheric effects at different wavelengths, Optical astronomy, radio astronomy, X-ray astronomy, telescopes and their characteristics, Modern Optical telescopes, Neutrino Astronomy, and Gravitational wave astronomy.

Unit – III: Astronomical Instruments- A (9 hours)
Atmospheric extinction, Photometer, Spectrographs, Charge Coupled Detector, Space astronomy, sensitivity, noise, quantum efficiency, Johnson noise, signal to noise ratio.

Unit-IV: Astronomical Instruments- B (9 hours)
Astronomical imaging, spectroscopy, polarimetry, calibration, adaptive optics, interferometry, speckle interferometry, aperture synthesis, and analysis of spectral lines.

Unit-V: Radiative Transfer (9 hours)
Black-body radiation, formation of spectral lines, Radiation field, Radiative transfer equation, Optical depth, thermodynamic equilibrium, radiative transfer through the stellar interior, Bremsstrahlung, Compton scattering, Thomson scattering, cyclotron and synchrotron radiation, opacity.

Textbooks

1. M. Zeilik and S. A. Gregory: *Introductory Astronomy and Astrophysics*, Saunders College Publication, 1998.
2. R. Bowers and T. Deeming: *Astrophysics I & II.*
3. Roy and Clarke. Astronomy Principles and Practice, Institute of Physics, 2003.
4. C. R. Kitchin. Astrophysical Techniques, 4th ed., Institute of Physics, 2003.
5. G B Rybicki and A P Lightman. Radiative Processes in Astrophysics, Wiley, 2004.

Further Readings

1. Smart, W.M., Spherical Astronomy, 6th ed., Cambridge University Press, 1977
2. Saha S. K., Diffraction-limited imaging with large and moderate telescopes, World Scientific, New Jersey, 2007.
3. Saha S. K. Aperture synthesis: Methods and Applications to Optical Astronomy, Springer, Berlin, 2010.
4. The Physical Universe by Frank Shu, University of California 1982 Sago.

PHYS 553 - ASTROPHYSICS–II (3 credits - 45 hours)

Unit – I: Stellar properties (9 hours)

Observational properties of stars – spectral and luminosity classification of stars- H-R Diagram, Saha equation, Star Formation-Jean's mass, Jeans Length, and Free fall timescale, Main Sequence Evolution, Mass- luminosity relation, White Dwarfs – Chandrasekhar's Limit, Neutron Stars, Pulsars, Supernovae, Stellar Black holes.

Unit – II: Solar atmosphere and active regions (9 hours)

Overview of Sun, Location of Sun, Sun's spectrum, Solar interior structure - Energy Generation, Radiative zone, Convection Zone, Observing the Sun, Solar Telescopes, Satellite Missions, Solar Polarimetry, Solar Radio Astronomy. Solar Atmosphere – Photosphere - active Regions, Sunspots – solar cycle, active and quiet Sun, Granulation, Faculae, Chromosphere -Diagnostics, Radiative Transfer, Heating, Supergranulation, Solar Flares-Properties, Classification, Occurrence, Prominences, Corona-Basic Facts, Observational Features, CME, Radio bursts, Solar Wind and Interplanetary Magnetic field.

Unit –III: Stellar structure (9 hours)

Hydrostatic Equilibrium, Mass conservation, Luminosity gradient equation, Temperature gradient Equations, Lane – Emden equation for polytrophic stars and its physical solution, estimates of central pressure and temperature, Radiation pressure, equation of temperature gradient for radiative and convective equilibrium, Schwarzschild criterion, gas pressure and radiation pressure, Linear Model and its properties, Volt – Russell theorem, Zero age main sequence, Mass – Luminosity relation.

Unit –IV: Interstellar Medium (9 hours)

Overview of the ISM, Types of interstellar media, Physical description of the ISM (various equilibria), Models of the ISM, Heating & cooling mechanisms, Thermal stability & equilibrium (2-phase models). Neutral atomic gas (HI regions): Interstellar UV & Visible absorption line observations, Radiative transfer in Lines & Line formation, line broadening mechanisms, Equivalent width, Interstellar HI Lyman absorption lines, Gas-phase abundance of metals, 21cm hydrogen line, 21cm line formation in absorption & emission. Strongmen sphere, Ionized gas (HII regions) & the physical processes.

Unit-V: Extra Galactic Astronomy (9 hours)

Galactic structure: local and large-scale distribution of stars and interstellar matter, the spiral structure, the galactic center. Galactic dynamics, stellar relaxation, dynamical friction, star clusters, density wave theory of galactic spiral structure, stellar populations, dark matter, redshift, neutrinos.

Textbooks

1. A. Hanslmeier: *The Sun and Space Weather*, Springer, 2007.
2. M. Schwarzschild: Structure and Evolution of Stars, Dover.
3. Supernovae & Nucleosynthesis – Arnett.
4. Introduction to Stellar Astrophysics, Vol. 3 Erika Bohm Vitense.
5. Textbook on Spherical Astronomy by WM Smart and R M Greene. CUP, 1986.

Further Readings

1. Stellar Structure & Evolution -- R. Kippenhahn & A. Weigert.
2. Principles of Stellar Evolution -- D. Clayton.
3. M. Berry: *Principles of Cosmology and Gravitation*, CUP, 1976.
4. Peacock: *Cosmological Physics*, CUP, 1998.
5. Kitchin. Stars, Nebulae and the Interstellar Medium, Taylor and Francis, 1987.
6. Herwitt M Astrophysical Concepts 3rd Edition, Springer Verlag 2006.

PHYS 554 - ASTROPHYSICS – III (3 credits - 45 hours)

Unit-I: Large Scale structure of the Universe (9 hours)
Expansion of the Universe, Hubble's Law, Evolution of the Universe, Dark matter, formation of galaxies, morphological classification of galaxies, Evolution of galaxies, Cluster of galaxies, large-scale distribution of galaxies, chemical evolution in the galaxy, interactions of galaxies, theory of Gravitational lensing.

Unit-II: The Milky Way Galaxy (9 hours)
Counting of stars in the sky, star clusters-globular-open- association, historical models, Morphology of the galaxy, different populations, Mass distribution, estimate of the total mass of the galaxy, Kinematics of the Milky Way, Differential rotation of the Galaxy, Rotational curves, Oort's constants, Galactic center, Super massive black hole, and jets.

Unit-III: Compact Objects (9 hours)
Radio galaxies, Active-galactic nuclei, Quasars – superluminal motion, Features of AGNs – luminosity and Taxonomy, formation of accretion disks, Unification scheme, neutron stars – density, degeneracy pressure, structure, pulsar, magnetic field of the pulsar, black holes, observational evidence of black holes.

Unit-IV: General Relativity and Cosmology (9 hours)
Foundations of general relativity, elements of tensor analysis, Schwarzschild and Kerr spacetimes, black hole physics, gravitational radiation, gravitational lensing, the redshift, distance measures, Pseudo- Newtonian cosmology, Dynamical evolution, cosmological solutions, age of the universe, matter content, dark matter, Cosmological constant, CMBR, observational tests. Theories of the universe, Big-bang, expansion of the universe, CMB radiation, Olber's paradox.

Unit - V: History of Universe: (9 hours)
Very early Universe, Primordial nucleo-synthesis, Baryogenesis, Cosmic neutrino background, Cosmic microwave background, anisotropies in CMBR, galaxies at high redshift, intergalactic medium, structure formation, matter-antimatter asymmetry in the Universe.

Textbooks:
1. J. Binney and M. Merrifield: *Galactic Astronomy*, Princeton University Press, 1998.
2. A. G. Lyne and F. G. Smith: *Pulsar Astronomy*, Cambridge University Press, 2012.
3. J. Binney and S. Tremaine: *Galactic Dynamics*, Princeton University Press, 1994.
4. Neutrino Astrophysics by J. Bahcall.
5. L. Spitzer: *Physical Processes in the Interstellar Medium*, John Wiley & Sons, 2008.
References:
1. J. Luminet: *Black Holes*, CUP, 1992.
2. Narlikar J V: *Introduction to Cosmology*, CUP.
3. Shapiro and Teukolsky. *Black Holes, White Dwarfs and Neutron Stars*, Wiley,1983.
4. T Padmanabhan. Theoretical Astrophysics: Vol. I, II and III. CUP, 2005.
5. General relativity and Cosmology by J V Narlikar. Macmillan Press 1979.