Syllabus

OF

Course Work

for

MASTER OF SCIENCE (M.Sc.)

PHYSICS

Choice Based Credit System (CBCS)

DEPARTMENT OF PHYSICS,
VEER NARMAD SOUTH GUJARAT UNIVERSITY,
UDHANA MAGDALLA ROAD,
SURAT -395007. (GUJARAT)

Proposed Structure for M.Sc. Syllabus

Effective from June 2017

SEMESTER- I

M.Sc. (PHYSICS)

Sr. No.	Course Code	Course Title	L	T	Cr.
1	PH-411	Mathematical Methods of Physics	4	1	4
2	PH-412	Classical Mechanics	4	1	4
3	PH-413	Measurement and Statistical Mechanics	4	1	4
4	PH-414	General Electronics	4	1	4
5	PH-415	Practicals	9	1	8
			25	05	24

Faculty Code: **Science** Subject Code: **PH** Level Code: **04**

Name of Program**: M.Sc.** Subject: **PHYSICS**

External Examination Time Duration: **03 Hours**

Name of Exam	Semester	PAPER No.	Course Group	Credit	Internal Marks	External Marks	Total Marks
M.Sc.	**1**	**PH-411**	**Core**	**04**	**30**	**70**	**100**
		PH-412	**Core**	**04**	**30**	**70**	**100**
		PH-413	**Core**	**04**	**30**	**70**	**100**
		PH-414	**Core**	**04**	**30**	**70**	**100**
		PH-415	**Practical**	**08**	**60**	**140**	**200**
			TOTAL	**24**	**180**	**420**	**600**

Faculty of Science **M.Sc. PHYSICS**

DEPARTMENT OF PHYSICS,
VEER NARMAD SOUTH GUJARAT UNIVERSITY,
SURAT -395007

M.Sc. Syllabus 2017
M.Sc. (Physics): SEMESTER-I

PH-411: Mathematical Methods of Physics

Unit 1 **Linear spaces**
Vector spaces and subspaces, Linear dependence and independence, Basis and Dimensions, linear operators, linear transformations

Unit 2 **Matrices and eigen values:**
Review of algebraic operations on Matrices, matrix representation, Similarity transformations, Inner product, Orthogonality, Unitary transformations, Eigen values and eigenvectors, Diagonalization using Jacobi method

Unit 3 **Ordinary Differential Equations**
Solution in closed form: First order differential equations, Linear equations, Bernoulli's equation, Exact equation, Clairaut's equation
Second order differential equation: Homogeneous and inhomogeneous forms, variation of parameters method, changes of variable.
Power series solution: General consideration, Legendre' equations, Bessel's equation, miscellaneous approximate methods, the W K B method.

Unit 4 **Special functions**
Legendre functions,: Rodrigue's formula, Integral representation, Generating function, recursion relations, orthogonality of Legendre's polynomial, Associated Legendre's polynomial ,it's recursion relations and orthogonality.
Bessel functions: Generating function, recursion relations and orthogonality of Bessel's function, Hermite functions, spherical harmonics, Lagaurre's functions.

Unit 5 **Integral transforms**
Fourier transform, Parseval's theorem, Laplace transforms, Properties of Fourier and Laplaces transforms ,Convolution theorem, other transform pairs, applications of integral transforms.
Complex integration:
Residue and residue theorem, contour integration

Unit 6 **Probability distributions**
Binomial, poison and Gaussian distribution, properties of distributions
Group theory :an introduction, Subgroup and classes, Group representation ,Applications

Recommended Books

1. J. Mathews and R.L.Walker Mathematical Methods of Physics Benjamin (IBH) (1979)
2. H. Margenau and G.M. Murphy, Mathematics of Physics and Chemistry, East-West Press (1975).
3. P.M. Morse and H. Feshbach, Methods of Theoretical Physics, Vols. 1-2, McGraw Hill-Kogekusha (1953).
4. R.V. Churchill, Complex Variables and Applications, McGraw Hill, (1960).
5. Mathematical Methods - B S Rajput Pragati Prakashan, (1997)
6. Mathematical Methods for Physicists George Arfken, Hans Weber, Frank E. Harris, Academic Press, 7th Edition (2012).

Theory Tutorials
PH – 411: Mathematical Methods of Physics
(Discussion and problem solving/exercise sessions)

1. Applications of series solution method
2. Problems on matrix inversion
3. Problems on Eigen value equation
4 Application of W.K.B. method
5. Problems of method of separation of variables for PDE.
6. Addition theorem of spherical harmonics
7. Problems on Fourier transform
8. Problems on Laplace transform
9. Problems on Gaussian distributions
10. Problems on binomial distributions

In addition to above the tutorial will also consist of solving problems given in the text and reference books.

M. Sc. (Physics): Semester-I

PH-412:- Classical Mechanics

Unit-1 Newtonian Mechanics of Many Particle Systems

Review mainly through examples of Newton's laws of motion; mechanics of system of particles; conservation laws.

Motion in a Non-Inertial Reference Frame:

Rotating coordinate systems; Coriolis force; motion relative to earth; limitations of Newton's programme.

Unit-2 Lagrangian Formulation

Constraints; their classification; generalized coordinates; Calculus of variations; Hamilton's principle; Lagrange's equations of motion; cyclic coordinates; conservation theorems and symmetry properties; Rayleigh dissipation function; Lagrange equation with undetermined multipliers.

Unit-3 Central Force Problem:

Reduction of two body problem to one body problem; equation of motion and first integrals; equivalent one-dimensional problem; classification of orbits; differential equation for the orbit; power law potentials; Bertrand’s theorem; Kelper's laws; Scattering in a central force field; Rutherford scattering cross section.

Unit-4 Rigid Body Motion:

Independent coordinates of a rigid body; Orthogonal transformations; transformation matrix; Euler-angles; Euler theorem; angular momentum; kinetic energy; moment of Inertia tensor; principal axis transformation; Euler's and Lagrangian treatment of rigid body motion; force free motion of a symmetrical top; motion of a heavy symmetrical top with one point fixed.

Unit-5 Small Oscillations:

Eigen-value equation and principal axis transformation; normal modes and normal coordinates for small oscillations; examples: Free vibrations of a linear tri-atomic molecule, coupled pendulums, double pendulum.

Hamilton’s Equations of Motion:

Legendre transformation and Hamiltonian function; canonical equations of motion; examples; ignorable coordinates and conservation theorems; Cyclic coordinates and Routh's procedure; modified Hamilton’s Principle.

Unit-6 **Canonical Transformations:**

I Generators of Canonical transformations, Equations of canonical transformations; examples; the Harmonic oscillator; The integral invariance of Poincaré and Lagrange and Poisson Brackets; Equation of Motion in Poisson bracket; Infinitesimal canonical transformation; constant of motion and symmetry properties; angular momentum Poisson brackets.

Hamilton-Jacobi Theory:

Hamilton-Jacobi equation; Hamilton's principal and characteristic function; examples; separation of variables in Hamilton-Jacobi equation; orbit equation for central force problem; periodicity and action angle variables, frequencies of periodic motion.

Recommended Books

1. H. Goldstein, Classical Mechanics, 3rd ed., Pearson education, 2nd ed., Addison Wesley, (2002).
2. J.B. Marion and S.T. Thronton, Classical Dynamics of Particles and Systems, 4th ed., Saunders College Publishing, (1995)
3. N.C. Rana and P.S. Joag, Classical Mechanics, TMH, (1991).
4. Y. R. Waghmare, Classical Mechanics, PHI, (1990).
5. V. B. Bhatia, Classical Mechanics, Narosa Pub. House, (1997).
6. R. G. Takwale and P. S. Puranik, Introduction to Classical Mechanics, Tata McGraw-Hill, (1990).
7. M. R. Spiegel, Theory and Problems of Theoretical Mechanics, Schaum's Outline Series. (2006).

Theory Tutorials (PH-412)

(These are mainly problem solving sessions. Concepts and other relevant aspects of theory course can also be discussed)

1. Solution of Mechanical problems with free body diagrams and use of Newton's laws; and conservation laws.
2. Examples of effect of Coriolis force and Foucault pendulum.
3. Examples of systems with different degrees of freedom; constraints.
4. Examples of Hamilton's principle
5. Examples of Lagragian formulation.
6. Motion of bodies under central forces which are not inverse-square.
7. Hard sphere scattering; problem on scattering.
8. Symmetric top using Euler's equations; moments of symmetric rigid bodies about their axis of symmetry.
9. Examples of small oscillations; normal modes.
10. Examples of Hamiltonian formulation.
11. Examples of canonical transformations.
12. Poisson bracket involving angular momentum.
13. Examples of Hamilton-Jacobi equations
14. Examples using action – angle variables and determination of frequencies.

M.Sc. Physics Semester-I

PH-413:- Measurement and Statistical Mechanics

Unit-1 **Measurement System**

Measurement, Definition of basic Terms, Calibration, The Generalized Measurement Systems, Static Characteristics - Some basic statistics, Static Sensitivity, Linearity, Threshold, Noise Floor, Resolution, Hystersis Scale Readability, spam, Dynamic Characteristics. Generalized Mathematical Model of Measurement System.

Unit-2 **Transducers**

Transducers, The Variable-Resistance Transducer, The Differential Transformer (LVDT), Capacitive Transducer, Piezoelectric Transducer, Photoconductive Transducer, Photovoltaic Transducer, Ionization Transducers, Hall-Effect Transducer, Digital Displacement Transducers, Problems.

Unit-3 **Measurements of Different Physical quentity**

Mechanical Pressure Measurement Devices, Low Pressure measurement, Ionization Gages, Dimensional Measurement, Force Measurement. Measurement of Viscosity, Humidity Measurement, pH Measurement, Detection of Nuclear radiation, Neutron Detection, Air Pollution standards.

Unit-4 **Quantum Statistical Mechanics**

The density matrix, quantum statistics of micro-canonical, canonical and grand canonical ensembles and their partition functions, system of indistinguishable particles, an ideal gas in a quantum mechanical micro-canonical, canonical and grand canonical ensemble, statistics of occupation numbers

Unit-5 **Ideal Bose and Fermi systems**

Thermodynamic behaviour of an ideal Bose gas, thermodynamics of blackbody radiation, elementary excitations of liquid He-II, Thermodynamic behaviour of ideal Fermi system,
Pauli para-magnetism

Unit-6 **Interacting systems and phase transition**

Cluster expansion of a classical gas, Mayer's cluster expansion, virial expansion of equation of state, evaluation of virial coefficients, cluster expansion of quantum mechanical system, gas of non-interacting particles, dynamical model of phase transitions, Ising model in zeroeth and first order approximation

Reference Books:

1. Measurement Systems - Application and Design. Earnest O. Doebein, Tata McGraw Hill Publication (5^{th} Edition) (2004)
2. Experimental Methods for Engineers J.P. Holman. Tata McGraw Hill Publication (7^{th} Edition) (2004).
3. Statistical Mechanics by R. K. Pathria and Baele, Academic Press, 3^{rd} Ed. (2011)
4. Thermodynamics and Statistical Mechanics, Greiner, Neise and Stocker, Springer (1995)
5. Introduction to Statistical Physics, Kerson Huang (H), Taylor and Francis (2001).
6. Statistical Mechanics by Franz Schwabl, Springer, 2^{nd} Ed. (2010)

Theory Tutorials (PH-413)

1. Concept of Measurement
2. Errors
3. Uncertainty Analysis
4. Chi-square Test
5. Statistics of occupation number calculation of thermo dynamical quantities
6. Blackbody radiation and photon statistics
7. Evaluation of second virial coefficients.
8. Fluctuations of thermo dynamical variables

M.Sc.- (Physics)- Semester - I
PH-414 : General Electronics

Unit-1 **Network analysis**

Review of Thevenion, Norton and Superposition theorems, Mesh and Node circuit analysis, T-Network analysis, π-Network analysis, conversions between T-Network section and π-Network section, Bridged-T network, Matrices method, Determinants method

Unit-2 **Bipolar Junction Transistor**

DC Model, BJT as Switch, BJT as an Amplifier, BJT Small-Signal Model, Frequency response of an amplifier, Low frequency response, High frequency response, Bandwidth, Step response of an amplifier.

Unit-3 **Operational Amplifier:**

Basic operational amplifier, Operational amplifier with negative feedback, Voltage series feedback amplifier: close loop voltage gain, input resistance, output resistance, voltage follower. Voltage shunt feedback amplifier: close loop voltage gain, input resistance, output resistance, Inverter. Application of operational amplifier: Summing, Scaling and Averaging amplifier, Integrator and Differentiator circuit. Active filters: First order Low pass, High pass, and Band pass filters.

Unit-4 **Oscillators and Generators:**

Oscillators, Phase shift oscillator, Wien-Bridge oscillator, Basic Comparator, Comparator characteristic, Square wave generator, Triangular wave generator, Saw tooth wave generator, Voltage regulators.

Unit-5 **Combinational digital circuit design:**

Standard Gate Assemblies, Arithmetic Functions, Digital Comparator, Parity Checker-Generator, Multiplexer, De-multiplexer, Encoder, Decoder, Digital to Analog Converter, Analog to Digital Converter Tri-State buffer, Read Only Memory (ROM), ROM applications.

Unit-6 **Sequential digital circuit design:**

The clocked S-R flip-flop, D flip-flop, J-K flip-flop T flip-flop and M-S flip-flop, Shift Registers, A-stable Multivibrator, Bi-stable Multivibrator, Mono-stable Multivibrator, Counters, Applications of counters, 7-Segment display, Alpha-Numeric display, Multiplexed display system.

Recommended Books

1. J.D. Ryder, Electronic Fundamentals and Applications Prentice Hall of India, (1981).
2. A Mottershed, Electron Devices and Circuits Prentice Hall of India, (1981).
3. J. Millmann and A grabel, Microelectronics, Mc Graw Hill, (1987).
4. A.S. Sedra and R.C. Smith, Microelectronics Circuits Oxford Press (1996).
5. R.A. Gaikwad, Op. Amps and linear Integrated circuits, Prentice Hall of India. (2002)

Theory Tutorials (PH-414)

1. Transistors, h-parameters
2. Feedback Amplifiers
3. Applications of Timer IC 555
4. Digital system designing
5. Electronic Instruments C.R.O., A.F.O., Multimeters, DMM, VTVM

M.Sc.- (Physics)- Semester - I

PH-415: Practicals

1. Numerical Analysis-I
2. Numerical Analysis-II
3. Computer Experiment –I
4. Normal Mode
5. Fourier Analysis
6. e/m Helical Method
7. Hall Effect
8. Ultrasonic Interferometer
9. Transducers-I
10. Michelson's Interferometer
11. Measurement of Wavelength of Laser by diffraction Method.
12. Measurement of Electrical Conductivity of Graphite.
13. Measurement of Energy Band Gap of a Semiconductor.
14. Characteristics of DIAC, TRIAC
15. Study of Inter conversion of 'π' and 'Ţ' Network
16. To design, build & Test relaxation Oscillator using UJT.
17. To design, build & Test Inverting and non-inverting Amplifier using Operational Amplifiers.
18. To design, build & Test combinational Logic circuit using only NAND/ NOR Gates.
19. To design, build & Test 04- bit Up/Down counter using IC 7493.

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PHYSICS

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DEPARTMENT OF PHYSICS,
VEER NARMAD SOUTH GUJARAT UNIVERSITY,
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SURAT -395007. (GUJARAT)

Structure for M.Sc. Syllabus
Effective from June 2017

SEMESTER- II

M.Sc. (PHYSICS)

Sr. No.	Course Code	Course Title	L	T	Cr.
1	PH-421	Quantum Mechanics -I	4	1	4
2	PH-422	Solid State Physics	4	1	4
3	PH-423	Classical Electrodynamics	4	1	4
4	PH-424	Numerical Analysis and Computer Programming	4	1	4
5	PH-425	Practical	9	1	8
			25	05	24

Faculty Code: **Science** Subject Code: **PH** Level Code: **03**

Name of Program**: M.Sc.** Subject: **PHYSICS**

External Examination Time Duration: **03 Hours**

Name of Exam	Semester	PAPER No.	Course Group	Credit	Internal Marks	External Marks	Total Marks
M.Sc.	**2**	**PH-421**	**Core**	**04**	**30**	**70**	**100**
		PH-422	**Core**	**04**	**30**	**70**	**100**
		PH-423	**Core**	**04**	**30**	**70**	**100**
		PH-424	**Core**	**04**	**30**	**70**	**100**
		PH-425	**Practical**	**08**	**60**	**140**	**200**
			TOTAL	**24**	**180**	**420**	**600**

Faculty of Science **M.Sc. PHYSICS**

DEPARTMENT OF PHYSICS, VEER NARMAD SOUTH GUJARAT UNIVERSITY, SURAT -395007

M.Sc. Syllabus 2017

M. Sc. (Physics): Semester-II

PH-421: QUANTUM MECHANICS - I

Unit 1 **Origin of Quantum Physics**

Particle aspect of radiation, wave aspect of particles, wave-particle duality, wave packets, wave packets and uncertainty relations, motion of wave packets.

Mathematical Tools of Quantum Mechanics:

The Hilbert space and Wave functions, Dimension and basis of vector space, Dirac notation, Operators, Hermitian adjoint, projection operators, parity operator, commutator algebra, uncertainty relations between two operators, eigen values and eigen vectors, unitary transformations, Matrix representation of kets, bras and operators, Change of basis and unitary transformations, wave functions in position and momentum space, Matrix representation of eigen value problem, Dirac delta function

Unit 2 **Postulates of Quantum Mechanics**

The basic postulates of Quantum Mechanics, Representation of state, representation of dynamical variables, Observables and operators, measurement in Quantum Mechanics, time evolution, stationary state, Schrodinger equation and wave packets, conservation of probability, expectation value, Ehrenfest theorem, symmetries and conservation laws

Unit 3 **One-dimensional and three-dimensional Problems**

The free particle, the particle in a box, The potential step, infinite square well, finite square well, The Harmonic oscillator by analytic and operator method, Hermite polynomials, harmonic oscillator wave functions, correspondence with classical theory, Spherically symmetric potentials in three dimensions, the spherical square well potential, the hydrogen atom, energy quantization, quantum numbers

Unit 4 **Angular Momentum**

Orbital angular momentum, general formalism of angular momentum, raising and lowering operators, matrix representation of angular momentum, Eigen functions and Eigen values of L^2 and L_Z using operator method, spherical harmonics, experimental evidence of spin, general theory of spin, spin ½ and Pauli spin matrices

Unit 5 Addition of Angular Momenta

Rotations in Classical Physics, rotations in Quantum Mechanics, Addition of two angular momenta, Clebsch-Gordon coefficients, coupling of orbiatal and spin angular momenta, tensor operators, spherical tensors, Wigner-Eckart theorem

Unit 6 Identical Particles

The principle of indistinguishibility**;** Symmetric and anti-symmetric wave functions; Spin and statistics of identical particles; The Slatter determinant; The Pauli exclusion principle; Spin states of a two electron system; States of the helium atom; Collision of identical particles.

Recommended Books

1. Quantum Mechanics by Nouredine Zettili (Wiley) 2nd Ed., (2004)
2. Quantum Mechanics by Franz Schawbl Springer 4th Ed. (2007)
3. Introductory Quantum Mechanics by Liboff, Pearson Education India, 4th Ed. (2003)
4. Quantum Mechanics by Claude Cohen-Tannoudji, Bernard Diu, Franck Laloe Vol. I & II, Wiley-CH, (1997)
5. Quantum Mechanics, by L. I. Schiff, McGraw-Hill Inc.,US, 3rd Revised Ed.(1968)
6. Introduction to Quantum Mechanics by David Griffiths, Pearson Education; 2nd Ed. (2015)
7. Quantum Mechanics, by A. K. Ghatak and S. Lokanathan (Macmillan -India), 5th Ed. (2004)
8. Quantum Mechanics by Mathews and Venkatesan, 2nd Ed. (2010)

Theory Tutorials

PH – 421: QUANTUM MECHANICS - I

(Discussion and problem solving/exercise sessions)

1. Insignificance of de Broglie hypothesis in macrophysics
2. General procedure to write down the Schrödinger equation for any system
3. Square potential barrier, quantum mechanical tunnelling
4. Relations giving the values of the commutators
5. Plotting of harmonic oscillator wave functions
6. Interpretation of hydrogen atom wave-functions
7. Problems in three dimensions : Anisotropic and Isotropic Oscillators
8. The algebra of rotation generators
9. Addition of angular momenta; L, S, J values for various atoms in periodic table.

In addition to above, the tutorial will also consist of solving problems given in the Text and Reference Books.

M. Sc. (Physics): Semester-II

PH-422- Solid State Physics

Unit 1 **Crystal Physics**

Crystal classes and Systems, Lattice, Lattice Points and space lattice, unit cells and lattice parameters, 2D and 3D lattices, Symmetry and Symmetry operations, Directions, Planes, and Miller Indices, Reciprocal lattices, Brillion Zones, Ideal and real crystal, Temperature dependence of reflection lines. Elastic scattering from Surfaces; Elastic scattering from amorphous solids.

Unit 2 **Crystal Defects**

Different type of imperfections, Schottky and Frenkel defects, edge and screw dislocationss, Grain boundaries and stacking fault. X-Ray diffraction, Powder Crystal method, Rotating Crystal method, Laue methods, other probes for Crystal Strecture determination.

Unit 3 **Lattice vibrations and thermal properties**

Vibrations of Monoatomic Lattice, normal mode frequencies, dispersion relation. Lattice with two atoms per unit cell, normal mode frequencies, dispersion relation., Quanization of lattice vibrations, phonon momentum, Inelastic scattering of neoutrons by phonons, Surface vibrations, Inelastic Neutron scattering. Anharmonic Crystal Interaction. Thermal conductivity - Lattice Thermal Resistivity.

Unit 4 **Diamagnetism and Paramagnetism**

Langevin diamagnetic equation, diamagnetic response, Quantum mechanical formulation, core diamagnetism. Quantum Theory of Paramagnetism, Rare Earth lons, Hund's Rule, Iron Group ions, Crystal Field Splitting and Quenching of orbital angular momentum; Adiabatic Demagnetisation of a paramagnetic Salt, Paramagnetic susceptibility of conduction electrons.

Unit 5 **Magnetic ordering**

Ferromagnetic order- Exchange Integral, Saturation magnetisation, Magnons, neutron magnetic scattering; Ferrimagnetic order, spinels, Yttrium Iron Granets, Anti Ferromagnetic order.

Ferromagnetic Domains - Anisotropy energy, origin of domains, transition region between domains, Bloch wall, Coercive force and hysteresis.

Unit 6 **Superconductivity**

Historical Introduction, Superconducting Materials, Josephson effect, The London Education, Ginzburg-Landau theory, The BCS theory, HTSC cuprate Material Characterisations properties of HTSC Oxides, Potential Applications of Super Conductivity.

Reference Books:

1. Introduction to Solid State Physics by Kittel, John Wiley & sons, 8th ed. (2004)
2. Fundamentals of Solid State Physics by J.Richard Chistman John Wiley & sons (1987).
3. Solid State Physics - Structure and properties of Materials by M.A. Wahab Narosa Publications (1999).
4. Elementary Solid State Physics by M. Ali Omar, Addison Wesley (LPE), (1994).
5. Solid State Physics- S.O. Pillai (3rd edition), New Age International Ltd. (2015).

Theory Tutorials
PH - 422 : SOLID STATE PHYSICS
(Discussion and problem solving/exercise sessions)

1. Review of Crystal Structure.
2. Space Group & Point Groups.
3. X-Ray diffraction Structure factor.
4. Phase diagrams of Binary alloys.
5. Problems on magnetic matrials.

In addition to above the tutorial will also consist of solving problems given in the text and reference books.

M.Sc.- (Physics)- Semester - II

PH-423: Classical Electrodynamics and Plasma Physics

Unit 1 **Multipole expansion**
Multipole expansions for a localised charge distribution in free space, Linear quadrupole potential and field, static electric and magnetic fields in material media, Boundary conditions.

Unit 2 **Maxwell's equations**
Displacement current, Maxwell's equations, Maxwell's equations in matter, boundary conditions, The continuity condition, Poynting's theorem, Maxwell's stress tensor

Unit 3 **Electromagnetic waves**
Waves in one dimension, boundary conditions: reflection and transmission, polarization, Electromagnetic waves in Vacuum, energy and momentum in electromagnetic wave, Electromagnetic waves in matter, Reflection and transmission at normal and oblique incidence, Electromagnetic waves in conductors, frequency dependence of permittivity, skin depth

Unit 4 **Potentials and fields**
Scalar and vector potential, Gauge transformations, Coulomb and Lorentz gauge, Retarded potentials and Lienard-Wiechert potentials, the fields of a moving point charge

Unit 5 **Wave Guides**
Rectangular wave guides, Transverse magnetic waves in rectangular wave guides, transverse electric waves in rectangular wave guides, TM and TE waves in circular wave guides

Unit 6 **Plasma Physics and magnetohydrodynamics**
Introduction of plasma physics and magnetohydrodynamics, magneto-hydrodynamic equations, magnetic diffusion, viscosity and pressure, magneto hydrodynamic flow between boundaries with crossed electric and magnetic fields, pinch effect, instabilities in a pinched plasma column, magneto hydrodynamic waves, plasma oscillations, De bye screening. Applications of plasma physics and controlled thermonuclear reactions.

Recommended Books

1. Introduction to Electrodynamics by David J. Griffiths. (1999)
2. Classical Electricity and Magnetism by Panofsky and Phillips, (2005)
3. Classical Electrodynamics by J. D. Jackson (1975)
4. Electromagnetic waves and Radiating systems by Jordan and Balmain
5. Foundations of Electromagnetic Theory by Reitz and Milford, (2008)
6. An Introduction to Magnetohydrodynamics by P A Davidson, Cambridge University Text, (2001)
7. Introduction to Plasma Physics and Controlled Fusion by F F Chen, Springer; 2nd ed. (1984)

Theory Tutorials
PH – 423: CLASSICAL ELECTRODYNAMICS AND PLASMA PHYSICS
(Discussion and problem solving/exercise sessions)

1. Calculation of multipole moments of discrete and continuous charge configuration.
2. Problem involving gauge other than Coulomb and Lorentz gauge.
3. Problem monopole and charge quantization.
4 Problem on Brewster angle, spreading of a wave propagating in a dispersive medium,
5. Problem on magnetic flux through a perfectly conducting loop.
6. Problem of net force on the hemisphere of uniformly charged solid sphere using Maxwell's stress tensor.
7. Problems on reflection and transmission coefficients
8. Energy associated with the skin depth of a conductor.
9. Radiation due to a cube with charge at alternate corners.
10. Problems on TE modes

In addition to above the tutorial will also consist of solving problems given in the text and reference books.

M.Sc.- (Physics)- Semester - II

PH- 424: Numerical Analysis and Computer Programming

Unit 1 **Numerical Integration:**

Newton-Cote's formula, Trapezoidal, Simpson 1/3rd and 3/8th rule and Weddle rules.

Numerical Solutions of Ordinary Differential Equations:

Euler, Picard and Taylor series methods, Runge–Kutta 2nd order and 4th order method, and Predictor Corrector methods

Unit 2 **Solution of Simultaneous Linear Equations**:

Matrix inversion method, Cramer's rule with Pivotal and triangle methods for determinants.

Eigenvalues and Eigenvectors of a Matrix:

Characteristic roots method, Jacobi method, Householder method.

Unit 3 & 4 **Operating systems, higher level compiler languages, algorithm; flow charting,**

FORTRAN Language

Character set, structure of a program, constants and variables, arithmetic expressions, arithmetic statement; assignment statements, input and output statements, control statements: IF-THEN-ELSE, arithmetic IF, logical expressions and assignments, GO TO, basic looping structure, Subscripted variables, DIMENSION statements; format specifications; OPEN and CLOSE statements; function statements, function subprograms and subroutines

Unit 5 & 6 **C-Language:**

Introduction to C language, identifiers and keywords, data types, constants and variables, arithmetic expressions; input and output statements, conditional statements: *while*-loop, *for*-loop, *do while*–loop; arrays; logical operators and expressions, structures: *switch*, *break* and *continue* statements; functions; structures; pointer data type; random and sequential files, file handling in C.

Programs:

Program writing in FORTAN and C for interpolation, integration, roots of equations, matrix diagonalization, solution of differential equations. Good programming practices.

Recommended Books

1. J. B. Scarborough, Numerical Mathematical Analysis, Oxford Books Co., 1962.
2. S. S. Sastry, Introductory Methods of Numerical Analysis. PHI, 1998.
3. K. S. Rao. Numerical Methods for Scientists and Engineers, PHI, 2001
4 V. Rajaraman, Computer Oriented Numerical Methods, PHI, 1994.
5. J. H. Mathews, Numerical Methods for Math., Science and Engineering, PHI, 1994
6. V. Rajaraman, Computer Programming in FORTRAN 77, PHI, 1994.
7. P. S. Grover, Programming and computing with FORTRAN 77 and 90.
8. V. Rajaraman, Computer Programming in C, PHI, 1997.
9. C. Xavier, C Language and Numerical Methods, 1999.
10. B.W. Kernigham and D.M. Ritchie, The C Programming language, PHI, 1988.

Theory Tutorial

(Discussion and Problem Solving Sessions)

1. Error in numerical compution, error in construction of a model, approximations.
2. Truncation error and their estimation.
3. Propagated rounding error and methods to minimize it.
4 Order of convergence of iterative procedures.
5. Analysis of errors in various interpolation formulas.
6. Errors in computed eiganvalues and eigenvectors.
7. Flow charts
8. Elementary programs using FORTRAN.
9. Elementary programs using C.

M.Sc.- (Physics)- Semester - II

PH- 425: Practicals

1. Numerical Analysis-III
2. Numerical Analysis-IV
3. Computer Experiment –II
4. 'e' by Milliken's Oil drop Method
5. Electron Spin Resonance
6. Measurement of Susceptibility of Liquid by Quinck's Methods
7. Lattice Dynamics
8. X-Ray Diffraction
9. Transducers-II
10. Electrical Conductivity of a Semiconductor using Four Probe Method.
11. Photo Cell
12. Measurement of 'h' by Solar Cell
13. Design build and test an Astable multivibrator
14. Design build and test a phase shift oscillator using operation amplifier
15. Design build and test regulated power supply.
16. Design build and test combinational logic circuit using multiplexer.
17. Design, build and test 4 bit R-2R ladder type DAC
18. To design, build and test a first order band pass filter using operational amplifier.

Syllabus

OF

Course Work

for

MASTER OF SCIENCE (M.Sc.)

PHYSICS

Choice Based Credit System (CBCS)

DEPARTMENT OF PHYSICS,
VEER NARMAD SOUTH GUJARAT UNIVERSITY,
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SURAT -395007. (GUJARAT)

Structure for M.Sc. Syllabus

Effective from June 2018

SEMESTER- III

M.Sc. (PHYSICS)

Sr. No.	Course Code	Course Title	L	T	Cr.
1	PH-531	Quantum Mechanics -II	4	1	4
2	PH-532	Nuclear and Particle Physics	4	1	4
3	PH-(E)-533	Physics of Semiconductor Devices	4	1	4
4	PH-(E)-534	Microcontroller and Applications	4	1	4
5	PH-(M)-533	Crystal Growth and Characterization	4	1	4
6	PH-(M)-534	Advanced Materials Science	4	1	4
7	PH-(T)-533	Non-linear Systems and High Performance-Computing	4	1	4
8	PH-(T)-534	Computational and Simulation methods in Physics	4	1	4
9	PH-(N)-533	Nuclear Radiation Detection and Accelerators	4	1	4
10	PH-(N)-534	Nuclear Reactions, Nuclear Energy and Nuclear Reactor Theory	4	1	4
11	PH-(C)-534	Practicals (Common)	3	0	8
12	PH-(E)-535	Practicals (Electronics)	6	1	8
13	PH-(M)-535	Practicals (Materials Science)	6	1	8
14	PH-(T)-535	Practicals (Theoretical Physics)	6	1	8
15	PH-(N)-535	Practicals (Nuclear Physics)	6	1	8
TOTAL			25	05	24

Faculty Code: **Science** Subject Code: **PH** Level Code: **05**

Name of Program**: M.Sc.** Subject: **PHYSICS**

External Examination Time Duration: **03 Hours**

Name of Exam	Semester	PAPER No.	Course Group	Credit	Internal Marks	External Marks	Total Marks
M.Sc.	3	PH-531	Core	04	30	70	100
		PH-532	Core	04	30	70	100
		PH-533	Elective	04	30	70	100
		PH-534	Elective	04	30	70	100
		PH-535	Practical	08	60	140	200
			TOTAL	24	180	420	600

Faculty of Science **M.Sc. PHYSICS**

DEPARTMENT OF PHYSICS, VEER NARMAD SOUTH GUJARAT UNIVERSITY, SURAT -395007

M.Sc. Syllabus 2017

M. Sc. (Physics): Semester-III

PH-531: QUANTUM MECHANICS-II

Unit 1 **Scattering Theory**

Kinematics of the scattering process: Differential and total cross-sections, Wave mechanical picture of scattering: The scattering amplitude, Green's function; Formal expression for scattering amplitude, The Born approximation, Validity the Born approximation

Unit 2 **Scattering Theory-Phase shifts**

Partial Waves Analysis: Asymptotic behavior of partial waves - phase shifts Optical theorem, Phase shifts- relation to the potential, potentials of finite range, Low energy scattering, scattering by a square well potential, Scattering by a hard sphere, Yukawa and Coulomb potential

Unit 3 **Approximation Methods for Stationary States**

Time independent perturbation theory, non-degenerate and degenerate case, applications to fine structure splitting,, Zeeman (normal and anomalous) effect, Stark effect.

The Variational method, upper bound on ground state, application to helium atoms and simple cases

The WKB method, Bohr-Sommerfield quantization condition, applications of WKB to simple cases

Unit 4 **Time dependent Perturbation Theory**

The Schrodinger Picture, Heisenberg picture, interaction picture, Time dependent perturbation theory, transition probability, first and second order transitions, constant perturbation, Harmonic perturbation, Fermi's golden rule, adiabatic and sudden approximations

Unit 5 &6 **Relativistic wave equations:**

Generalization of the Schrödinger equation, The Klein-Gordon equation: Plane wave solutions; Charge and current densities, The Dirac's Equation: Properties of Dirac matrices, Dirac equation in covariant form, Plane wave solutions of the Dirac equation; Energy spectrum, The spin of the Dirac particles, Significance of the negative energy states.

Recommended Books

1. Quantum Mechanics by Nouredine Zettili (Wiley) 2nd Ed. (2004)
2. Quantum Mechanics by Franz Schawbl Springer 4th Ed. (2007)
3. Introductory Quantum Mechanics by Liboff, Pearson Education India, 4th Ed. (2003)
4. Quantum Mechanics by Claude Cohen-Tannoudji, Bernard Diu, Franck Laloe Vol. I & II, Wiley-CH, (1997)
5. Quantum Mechanics, by L. I. Schiff, McGraw-Hill Inc.,US, 3rd Revised Ed. (1968)
6. Introduction to Quantum Mechanics by David Griffiths, Pearson Education; 5th Ed. (2015)
7. Quantum Mechanics, by A. K. Ghatak and S. Lokanathan (Macmillan -India), 5th Ed.
8. Quantum Mechanics by Mathews and Venkatesan, 2nd Ed. (2010)

Theory Tutorials
PH – 531: QUANTUM MECHANICS - II
(Discussion and problem solving/exercise sessions)

1. Propagator for a free particle
2. Comparison of Schrödinger, Heisenberg and interaction pictures
3. Problems on various time independent perturbations
4 Problems on time dependent perturbations
5. Problems on WKB method
6. Problems on scattering theory
7. Problems on Born approximation
8. Scattering by different potentials
9. Problems on Phase shift
10. Partial wave analysis of scattering from simple potentials

In addition to above the tutorial will also consist of solving problems given in the text and reference books.

M. Sc. (Physics): Semester-III

PH-532: Nuclear and Particle Physics

Unit 1 *Brief history*: developments in nuclear and particle physics. Fundamental interactions, classification of particles: fermions, bosons, leptons, hadrons (mesons and baryons), excited states, resonances.
Nuclear properties: nomenclature, symbols, charge, mass, charge and potential radii, spin, statistics, isospin, magnetic dipole moment, electric quadrapole moment, binding energy.
Nuclear force: saturation property, charge independence, exchange forces, tensor force, symmetry and nuclear force, low energy n-p and p-p scattering, low energy scattering parameters, nuclear potential, Intermediate bosons.

Unit 2 ***Nuclear Models***
Liquid-drop model: semiempricial mass formula, nuclear stability
Single Particle Shell Model: evidence of shell structure, magic numbers, Spin-orbit coupling, parity, spin and moments of nuclear ground states, Schmidt lines,
Collective Models: evidence for collective motion, brief introduction to vibrational and rotational states, single particle motion in deformed potential.

Unit 3 *Gamma Transitions*: Measurement of life-times of excited states, theoretical predictions of decay constants, selection rules, angular correlation, internal conversion.
Beta Decay: Fermi theory of beta decay, Kurie plots, comparative half-lives, selection rules, electron capture decay, parity violation in beta decay, double beta decay.
Alpha Decay: Barrier penetration, reduced widths of alpha unstable states, energy levels

Unit 4 *Nuclear Reactions*: Theories of nuclear reactions, partial wave analysis of reaction cross-section, Compound-nucleus (CN) formation and breakup, resonance scattering and reaction, optical model of particle induced nuclear reactions, direct reactions- theory of stripping reactions, Spontaneous fission, induced fission, fission theories, heavy-ion reactions.

Unit 5 *Symmetries*: Discrete and Continuous symmetry transformations, symmetry and degeneracy, conservation laws, parity, charge conjugation and time reversal, CPT theorem (statement), Permutation symmetry, Isospin, G-parity, strangeness, charm, beauty quantum numbers; need for color, Gell-Mann Nishijima Scheme; Multiplets of $SU(2) \otimes U(1)_Y$

Unit 6 *Standard Model*: quarks and leptons, isospin of antiparticles, isospin of quarks, static quark model of hadrons: mesons; pseudoscalar mesons; vector mesons, Baryon singlet; Baryon octet; magnetic dipole moment of baryon octet, hadrons mass and quark–quark interaction.

Recommended Books

1. H.A. Enge, Introduction to nuclear Physics, Addison Wesley, 1982.
2. S.S.M. Wong, Introductory Nuclear Physics, PHI, 2002.
3. M.P. Khanna, Introduction to Particle Physics, PHI, 2004.
4. W.E. Burcham and M. Jacobs, Nuclear and Particle Physics, Addison, Wesley, 1998.
5. D.H. Perkins, Introduction to High Energy Physics, Addison Wesley, 1987.
6. B. L. Cohen, Concepts of Nuclear Physics, TMGH, 1984
7. Y. R. Waghmare, Introductory Nuclear Physics, Oxford-IBH, 1981
8. A. Das and T. Ferbel, Introduction to Nuclear and Particle Physics, 2nd ed. World Scientific, 2003.
9. H.S. Hans, Nuclear Physics, Experimental and Theoretical, New Age International (P) Ltd, 2001.
10. Kenneth S. Krane, Introductory Nuclear Physics, John Wiley & sons. Inc. Reprint Edition, 2014.

Theory Tutorials
PH-532: (Nuclear and Particle Physics)
(Discussion and problem solving sessions)

1. Calculation of nuclear binding energy.
2. Shell model, collective model.
3. SU(2), SU(3)
4. Quarks, charge, mass, flavour, colour etc.
5. About W^{+} and Z bosons.
6. Idea of parity and its violation.
7. Exoergic and endoergic reactions.
8. Idea of basic interactions and their unification.
9. Application of carbon dating C^{14}.
10. Idea of radioactive sources, their production.
11. Use of radioactive sources in industry and other branches of science.
12. General properties of Nuclear forces.

M.Sc. (Physics): Semester - III

(Specialization: Electronics)

PH(E)-533 : Physics of Semiconductor Devices

Unit 1 **Introduction**

Carrier transport phenomena: Mobility, Resistivity and Hall Effect, Recombination process, Phonon spectra, optical thermal and high field properties of semiconductor, basic equation for semiconductor device operation.

Unit 2 **P-N Junction Diode**

Depletion region and depletion capacitance, Abrupt and linearly graded junctions, Current-Voltage characteristics, Ideal case- Shockley equation, Generation and recombination, High injection condition, Diffusion capacitance, Junction breakdown, Thermal instability, Tunneling effect, Avalanche multiplication, Terminal function, Heterojunction .

Unit 3 **Bipolar transistor**

Bipolar transistors, Static characteristic, Microwave transistors, Cutoff frequency, Microwave characterization, Device geometry and performance, Power transistors, switching transistor.

Unit 4 **Thyristor**

Basic characteristic, Shockley diode and three terminal Thyristor: Static I-V Characteristic, Turn-On and Turn-Off time, Cathode short and dV/dt Effect, Maximum operation frequency. Related power thyristor: Reverse conducting Thyristors, Light activated Thyristor, DIAC and TRIAC, Uni- Junction Transistor and trigger Thyristor

Unit 5 **M-S Contact**

Energy band relation, Schottky effect, Characterization of barrier height, General expression of barrier height, Measurement of barrier height, Barrier height adjustment, Ohmic contact.

Unit 6 **Optical Devices**

Optical absorption: Photon absorption coefficient, Electron –Hall pair generation, Solar cell: PN Junction solar cell, Conversion efficiency and solar concentration, Heterojunction solar cell, Amorphous silicon solar cell, Photo-detectors, PIN photodiode, Phototransistor, Light emitting diode, Laser diode.

Recommended Books:

1. D.A. Neamen, Semiconductor Physics and devices, Tata McGraw-Hill Publishing Company Limited. (2002).
2. S.M. Sze, Physics, of semiconductor devices, Wiley-Interscience, (1981).
3. B.G. Streetman, Solid State Electronic Devices, Prentice-Hall of India Private Linlited 3rd Ed.(1994).
4. R.M. Warner and B.Z. Grang, Transistors, John Wiley, (1983).

PHYSICS OF SEMICONDUCTOR DEVICES

(Discussion and problem solving/exercise sessions)

1. Importance and Effects of carrier transportation in semiconductors.
2. Applications of diodes.
3. Transient behavior of the Diode.
4. Applications of switching transistor.
5. Comparison between microwave transistor and switching transistors.
6. Applications of Laser's.
7. Circuit design for photo detection techniques.
8. Applications of LED.
9. Circuit design for power control using power devices.

M.Sc. (Physics) : Semester –III

(Specialization: Electronics)

PH(E)-534 : Microcontroller Applications

Unit 1 Numbering systems and Binary Arithmetic, Binary Arithmetic circuit design, Binary Codes, Character code, Numeric code, Packed and unpacked BCD numbers, Gray codes, Error correction and detection codes, Specialized codes, memory elements, primary and secondary storage, Memory organization in computer, microprocessor and microcomputers.

Unit 2 **8051 Architecture**: 8051 Hardware, 8051 Block diagram, 8051 Programming model, 8051 Oscillators and clock, Internal memory, Stack and stack pointer, Special Function Registers, Input / Output pins ports and circuits, External memory, Counters and Timers, TCON-SFR, TMOD-SFR, Timer Counter Interrupts, Timing, Timer Mode of Operation, Counting, Serial data Input / Output, SCON-SFR, PCON-SFR, Serial Data interrupts, Data transmission and reception, Serial data transmission Modes, Interrupts, IE-SFR, IP- SFR, Timer flag Interrupt, Serial Port Interrupt, External Interrupt, Reset, Interrupt control, Interrupt Priority, Interrupt Destinations, Software-Generated Interrupts,

Unit 3 **Moving data**: Addressing modes, Immediate addressing mode, Register addressing mode, Direct addressing mode, Indirect addressing mode, External data moves, Code memory Read-Only data moves, Push and Pop codes, Data exchanges, Example Programs.

Unit 4 **Logical operation:** Byte level logical operation, Bit level logical operation, Internal RAM bit addresses, SFR bit addresses, Bit level Boolean operation, Rotate and Swap operation, Example Programs.

Unit 5 **Arithmetic operation:** Flags, Instruction affecting flags, Incrementing and Decrementing, Unsigned addition, Signed addition, Unsigned subtraction, Signed subtraction, Multiplication, Division, Decimal arithmetic, Example Programs.

Unit 6 **Jump and Call instructions:** Jump and Call program range: Relative range, Short absolute range, Long absolute range, Jumps: Bit jumps, Byte, jumps, Unconditional jumps, Calls and Subroutine: Subroutine, Calls and stack, Calls and returns, Example Programs.

Recommended Books:

1. Kenneth J. Ayala, The 8051 microcontroller, Architecture, programming and application, West publishing company (1996).
2. M.A.Mazidi, J.G.Mazidi, Rolin D. McKinlay The 8051 Microcontroller and Embedded Systems. Pearson Prentice Hall (2000).
3. Satish Shah, Embedded system design using The 8051 Microcontroller, OUP India (2010).

Theory Tutorials

PH(E)-534 :Microprocessor and Applications

(Discussion and problem solving/exercise sessions)

1. Delay calculations
2. Delay Programs in assembly language
3. I/O Port programming in assembly language
4. Delay Programs in C-language
5. I/O Port programming in C-language
6. Logic operations in C-language
7. Data conversation in C-language

M. Sc. (Physics): Semester-III

PH(E)-535 (Practicals)

(Specialization: Electronics)

Group-A Experiments

Note:

Practical consist of experiments in two groups **A** and **B**.

Group **A** experiments are common for all the specializations.

Group **B** experiments are different for different specializations.

Group A: List of Experiment **(3 hours/ week + 1 hour/week tutorial)**

Numerical Analysis Exercises:

1. Interpolation and inverse interpolation using Lagrange's formula.
2. Numerical integration using Simpson's 1/3rd rule.
3. Solving ordinary differential equations using Runge-Kutta method.

FORTRAN Programming Exercises:

4. Writing and testing FORTRAN programs for Interpolation and inverse interpolation using Lagrange's formula.
5. Writing and testing FORTRAN programs for Numerical integration using Simpson's 1/3rd rule.
6. Writing and testing FORTRAN programs for solving ordinary differential equations.

Laboratory Tutorial

Discussion of techniques of actual numerical computation, program writing concepts, error analysis to supplement actual exercise given for numerical analysis and computer programming.

Group B: List of Experiments (6 hours/ week)

Specialization: Electronics

1. To design, build and test a Mono-stable multivibrator.
2. To design, build and test a Bistable multivibrator.
3. To design, build and test a Voltage to Frequency converter
4. To design, build and test Schmitt Trigger circuit.
5. To design, build and test Saw tooth Generator with adjustable slop.
6. To design, build and test Adjustable Voltage Regulator.
7. To design, build and test a Window Detector.
8. To design, build and test a BCD to 7-Segnment ROM.
9. To design, build and test 4-bit binary Counter with Up/Down control.
10. To design, build and test 4-bit Mod-N Counter.
11. To design, build and test Digital to Analog converter.
12. Experiments on Microwave Bench.
13. Workshop practice. (Fitting and Turning)
14. Study of designing and preparing PCB.
15. Microcontroller Programming.

Recommended Books:

1. David A Bell, Solid State Pulse circuits, Eastern Economy Edition, PHI (2009).
2. R.A. Gaikwad, Op. Amps and linear Integrated circuits, PHI (2002).
3. M.A.Mazidi, J.G.Mazidi, Rolin D. McKinlay The 8051 Microcontroller and Embedded Systems. Pearson Prentice Hall, (2000).
4. A.P.Malvino, D.P.Leach, Digital principal and applications, McGraw-Hill Education, (2014).
5. S. K. Hajra Choudhury, Nirjhar Roy, A. K. Hajra Choudhury, Elements of Workshop Technology (Volume - 1), (2008) .

M. Sc. Physics Semester-III

(Specialization : Materials Science)

PH(M)-533: Crystal Growth and Characterization

Unit 1 The Historical Development of Crystal Growth, Significance of Single Crystals, Reasons for growing crystals, Crystal Growth Techniques. Melt Growth Techniques, Solution Growth Techniques, Vapor Growth Techniques, The Chemical Physics of Crystal Growth.

Unit 2 Nucleation, Classical theory of Nucleation, Homogeneous Nucleation, Heterogeneous Nucleation, Kinetics of Crystal Growth, Theories of Crystal Growth.

Unit 3 Need for Crystal Growth, Target of Crystal Growth, Furnaces, design and fabrication of a crystal puller.

Unit 4 Applications of Synthetic Crystals, Crystals in atmosphere, Ice Nucleation, Cloud seeding experiments, Food Seeding experiments.

Unit 5 Qualitative and chemical Analysis : Introduction, stages of Analysis, selection of Analysis Method, Searching of Literature, Chemical Analysis, Thermal Analysis (TGA, DTA, DSC, etc.),x-ray Analysis (XRD, EDAX, etc.)

Unit 6 Spectroscopic Methods: Introduction, Infrared spectroscopy (IR, FTIR) Ultraviolet spectroscopy, Raman Spectroscopy, Optical microscopy and morphology studies, SEM, TEM and AFM.

Recommended Books:

1. P. Ramaswamy & Santhan Raghavan Crystal Growth, KRU Publications, Chennai (2000)
2. Henisch H. K.Crystal Growth in Gel, The Pennsylvania state University Press , London (1973)
3. Vogel A. I., Elementary Practical Organic Chemistry part-2, Qualitative Organic Analysis, Longmans Green and Co. Ltd. (1966)
4. Crystal Growth Method – A. R. Patel

Theory Tutorials

PH(M)– 533: Crystal Growth & Characterizations

(Discussion and problem solving/exercise sessions)

1. Study of Natural Crystals
2. Growth Study of Diamonds
3. Growth Study of Bio-Materials
4. Morphology study of crystals
5. Crystal Growth Models and their limitations
6. Tools for property determination

M.Sc.- (Physics)- Semester - III
(Specialization: Materials Science)
PH(M)-534 : Advanced Materials Science

Unit 1 Material and Civilization, Material Science and Engineering, Classification of Engineering Materials, Levels of Structure, Structure-Property Relationship in Materials, Materials Science in India.

Unit 2 States of Matter, -Theory of Liquids, Structures of Solids, Colloidal state of Matter, Gel, Emulsion, Emulsifier, Liquid Crystals, Applications of liquid crystals, The Plasma State of Matter, Criterions for plasma state, applications of plasma.

Unit 3 Advanced Materials, -Smart Materials Quantum Dots, Spintronics, Polymer, Ceramics, Biomaterials, Composites, Macromolecules-Protein, Lipid, Nucleoid

Unit 4 Polymers, Classification of Polymers, Structure of long chain Polymer, Crystallinity of long chain Polymers, Ceramics, Classification of Ceramics, Properties of Ceramics, Applications of Ceramics.

Unit 5 Composite, Particulate Reinforced Composites, Fibre Reinforced Composites, Laminuted Composite, Polymer Matrix Composites, Metal Matrix Composite, Ceramic Matrix Composites, Applications of Composite.

Unit 6 Nano-materials, Fullerenes, History of Nano Materials, How is the nanoworld is different from the world around us? Begining of Nano-science, Nano-materials, Properties of Nano-materials, seeing nano-objects, Preparation of Nano-materials, Nano-biotechnology, Molecular Motors, Nano-cosmetics, Nano in Textiles. Drug Delivery, Cancer Therapy, Tissue Engineering, Lab-on-chip (LOC), Nano-lithography, Future Lighting, MRI With magnetic Nano-particles.

Recommended Books:

1. S. K. Kakani Amit kakani, Materials science – New Age International publishers (2005)
2. L. H. Van vlack, Elements of Materials Science and Engineering (sixth Edition) Addision – Wesley publishing company. (1999)
3. A. G. Gay, Essential of Material science – Mc Graw Hill, (1976)
4. Manas Ghande, Science of Engineering Materials Vol- 3, Mc Millan Publisher, India, (1980)
5. C. N. R. Rao, Indumatti Rao, Jatinder Kaur, Nanoworld - An Introduction to Nano Science and Nano-techonology. Jawaharlal Nehru Center for Advanced Scientific Research - Publications (2010).

Reference Books:

1. Materials Science and Metallurgy U.C. Jindal, Atish Mozumder Pearson-Dorling Kindersley (India) Pvt. Ltd. Third Edition (2013)
2. Material Science and Metallurgy Parashivamurthy K.I. Pearson-Dorling Kindersley (India) Pvt. Ltd. First Edition (2012)
3. Materials Science - An Intermediate Text Willam F. Hosford, Cambridge University Press, First Edition (2007)
4. V. Raghvan, Materials Science and Engineering - A First Course (Fifth Edition), Prentice - Hall of India Publishers, New Delhi (2005)

Theory Tutorials

PH(M) – 534: Advanced Materials Science

(Discussion and problem solving/exercise sessions)

1. Scopes and Trends in Materials Science
2. Advances in Nano-materials
3. Advances in Composites
4. Advances in Ceramics
5. Alloys and Their Phase Diagrams
6. Selection of Materials for industrial applications

M. Sc. (Physics): Semester-III
PH(M)-535 (Practicals)

(Specialization : Materials Science)

Group-A Experiments

Note:

Practical consist of experiments in two groups **A** and **B**.

Group **A** experiments are common for all the specializations.

Group **B** experiments are different for different specializations.

Group A: List of Experiment **(3 hours/ week + 1 hour/week tutorial)**

Numerical Analysis Exercises:

1. Interpolation and inverse interpolation using Lagrange's formula.
2. Numerical integration using Simpson's $1/3^{rd}$ rule.
3. Solving ordinary differential equations using Runge-Kutta method.

FORTRAN Programming Exercises:

4. Writing and testing FORTRAN programs for Interpolation and inverse interpolation using Lagrange's formula.
5. Writing and testing FORTRAN programs for Numerical integration using Simpson's $1/3^{rd}$ rule.
6. Writing and testing FORTRAN programs for solving ordinary differential equations.

Laboratory Tutorial

Discussion of techniques of actual numerical computation, program writing concepts, error analysis to supplement actual exercise given for numerical analysis and computer programming.

Group B: List of Experiments **(6 hours/ week)**

Specialization: Materials Science

1. Stereographic Projection of Crystal Modes
2. Laue Experiment
3. Curie temperature of Novel Metal
4. Measurement of dielectric constant of ferroelectric materials
5. Measurement of magnetic susceptibility of materials
6. Non Destructive Test
7. Magnetostriction set up
8. Speed of a vacuum motor
9. Holography
10. Thermal and Electrical Conductivity of Metal
11. Specific heat of solids
12. Dielectric Constant
13. Study of divergence of a Laser beam
14. Study of Light pipes and Fiber optics
15. Growing the single crystal from solution
16. Micro hardness study
17. Morphological Studies and Use of Research Microscope
18. Etching of crystals.

M. Sc. (Physics): Semester-III
(Specialization : Theoretical Physics)
PH(T)-533: Non-linear Dynamics and High-Performance-Computing

Unit 1 & 2 **Mathematica for Theoetical Physics**

- Introduction: interfaces, numerical and algebraic calculations.
- Symbolic mathematics: differentiation, integration, sums and products, solving equations, differential equations, power series, and limits, integral transforms, recurrence equations.
- Numerical mathematics: numerical sums, products and integrals numerical equation solving, numerical differential equations, optimization
- Functions and programs
- Lists
- Graphics and sound
- Input/output
- File operations

Unit 3 **Nonlinear Ocillations:**

Phase space trajectories of Harmonic oscillator, damped harmonic oscillators, Singular Points of trajectories; Nonlinear Oscillations using *Mathematica*; Linstedt-Poincaré method for a mathematical pendulum, Volterra's Problem; Limit Cycles.

Unit 4 **Chaos:**

Introduction to Chaos; Discrete mapping and Hamiltonian, Logistic Maps; Poincaré Sections; Strange Attractors; Intermittency, Crisis and Quasi-periodicity, Lyapunov exponent.

Non-linear Dynamics:

Introduction to Non-linear dynamics, the Korteweg-deVries equation and its numerical solution, the inverse scattering transform using *Mathematica*.

Unit 5 Essentials of parallel computation, need for high speed computing and parallel computers, temporal and data parallelism, pipelined parallel computers, array processors, generalized structure of a parallel computer, shared memory multiprocessors, message passing multiprocessors, multilink multidimensional multi-computers. Programming parallel computers for High-Performance Computing (HPC).

Unit 6

- Software issues in Parallel Computing.
- **FORTRAN 90**: additional features different from FORTRAN 77 such as named constants, conditional operators, loops, CASE statement, arrays, variable dimensions, pointers, given functions, masking, sub-arrays, MODULES, INTERFACE, WHERE.
  FORTRAN 95: features for parallel computers, FORALL etc.

Recommended Books

1. S. Wolfram, Mathematica book, 5th ed. 2003.
2. Patrick T. Tam, A Physicist's Guide to Mathematica, 2nd ed., Elsevier, 2008
3. Andrey Grozin, Introduction to Mathematica for Physicists, Springer, 2014
4. V. B. Bhatia, Classical Mechanics, Narosa Pub. House, 1997
5. Lui Lam (editor), Introduction to Nonlinear Dynamics, Springer 1997
6. Gerd Baumann, Mathematica for Theoretical Physics-Classical Mechanics and Non-linear Dynamics, 2nd ed., Springer, 2005
7. Stephen Lynch, Dynamical Systems with Applications using Mathematica, Birkhaüser Boston, 2007
8. V.Rajaraman, Elements of Parallel Computing, PHI, 2006
9. V.Rajaraman and C. Siva Ram Murthy, Parallel Computers: Architecture and Programming, 2004.
10. V.Rajaraman, Computer Programming in Fortran 90 and 95, PHI, 1999.
11. P.S. Grover, programming and computing with FORTAN 77-90, Allied publishers, 1990.
12. A. Grama, A. Gupta, G. Kryapis, Vipin Kumar, Introduction to Parallel Computing, 2nd ed, Addison Wesley, 2003

Theory Tutorials

PH(T)-533: Computer Applications in Physics

(Discussion and problem solving/exercise sessions)

1. Solving differential equations using Mathematica.
2. Exercises on differentiation and integration using symbolic manipulation in Mathematica.
3. Multiplication of two matrices in Mathematica.
4. Finding real roots of a transcendental equation using Mathematica.
5. Solving linear and non-linear harmonic oscillator problems using Mathematica.
6. Some exercises on chaotic and non-linear systems using Mathematica.
7. Discussion on parallelization in matrix multiplication.
8. Survey on different supercomputers and parallel machines with their speeds in FLOPS.
9. Program for matrix multiplication in FORTRAN 77 and FORTRAN 90.
10. Program for matrix multiplication using parallelization in FORTRAN 95.

M. Sc.- (Physics) - Semester - III

(Specialization: Theoretical Physics)

PH(T)-534: (Computational and Simulation methods in Physics)

Unit 1

- *LU decomposition methods for solution of linear algebraic equations*:
  Lu decomposition, Gauss elimination and LU decomposition, Crout decomposition with substitution step, Matrix inverse using LU decomposition, tridiagonal systems, Cholesky decomposition.
- *Spline Interpolation*:
  Linear, Quadratic, and Cubic Spline fitting.
- *Least squares fitting techniques*:
  Least square techniques for fitting linear, quadratic, exponential and power law curves.

Unit 2

- *Eigen value problem*:
  power method, location of bound, largest and smallest eigen values.
- Richardson's extrapolation, Romberg integration.
  Gauss Quadrature, improper integrals.

Unit 3

Partial Differential Equations:

- *Finite-difference method for Elliptic equations*: Laplace equation, Laplacian difference equation, the Liebmann method, secondary variables, derivative boundary conditions, irregular boundaries; example a heated plate.
- *Finite-difference method for Parabolic equations*: the heat conduction equation, explicit methods, derivative boundary conditions, implicit method, Crank-Nicolson method, example-heat conduction over a long thin rod. parabolic equation in two spatial dimensions: the alternating-direction-implicit (A.D.I.) scheme, example: a heated plate.

Unit 4

- *Simulation of one-dimensional motion*:
  Falling object, oscillatory motion (with and without damping),
  Model of an accelerating car.
- *Simulation in two-dimensions*:
  Projectile motion.
- Simulation of RC, LR, and LRC circuits.

Unit 5

- *Basics of simulative Classical Molecular Dynamics*:
  Intermolecular potential, the numerical algorithm, boundary condition, molecular dynamics program, microscopic quantities, transport quantities
- Rutherford scattering.

Unit 6

- *Simulation of Quantum systems*:

Time-independent Schrödinger equation: infinite square well, perturbation on the ground-state of infinite square well, finite square well, harmonic oscillator, anharmonic oscillator.

Time-dependent Schrödinger equation: motion of a free wave-packet, motion of a wave-packet incident on a potential step, motion of a wave-packet inside an infinite well.

Variational quantum Monte Carlo methods: Ground-state of the harmonic and anharmonic oscillators, Monte Carlo calculation of square well potentials

Monte Carlo simulations: Modeling of Radioactive decay.

Recommended Books

1. S.C. Chapra, R.P. Canale, Numerical methods for Engineers, 5^{th} ed., McGraw Hill, (2006).
2. K. Sankara Rao, Numerical Methods for Scientists and Engineers, PHI, (2001).
3. M. L. Dejong, Introduction to computational physics, Addison Wesley, (1977).
4. T. Pang, An introduction to computational physics, Cambridge Uni. Press, (1971).
5. H. Gould and Tobochnik, An Introduction to computer simulation methods, vols. 1-2, Addison Wesley, (1988).
6. S.E. Koonin, Computational Physics, Addison Wesley, (1986).
7. R. C. Verma, Computer Simulation in Physics, Anamaya Publishers, (2004).
8. G.I. Duchi, spreadsheet Applications for Scientists & Engineers, Addison-Wesley, (1988).

Theory Tutorials

PH(T)-534: (Computational and Simulation methods in Physics)

(Discussion and problem solving/exercise sessions)

1. Problem on LU decomposition method.
2. An example for cubic Splines method
3. Find all the Eigen values of a 3x3 matrix using power method.
4. Propagation of inherent error in Romberg integration method.
5. Write program for FFT.
6. Solve projectile motion problem and compare simulation results with your calculations.
7. Derive Rutherford scattering formula.
8. Generate a random distribution of N particle positions in a cubical box of side L and calculate the total potential energy of this system for two-body Lenneard Jones potential.
9. List applications of molecular dynamics.
10. Simulate a quantum particle in an infinitely deep potential well.
11. Simulate the motion of a wave-packet.
12. Describe random-walk problem.

M. Sc. (Physics): Semester-III

PH(T)-535 (Practicals)

(Specialization: Theoretical Physics)

Group-A Experiments

Note:

Practical consist of experiments in two groups **A** and **B**.

Group **A** experiments are common for all the specializations.

Group **B** experiments are different for different specializations.

Group A: List of Experiment **(3 hours/ week + 1 hour/week tutorial)**

Numerical Analysis Exercises:

1. Interpolation and inverse interpolation using Lagrange's formula.
2. Numerical integration using Simpson's $1/3^{rd}$ rule.
3. Solving ordinary differential equations using Runge-Kutta method.

FORTRAN Programming Exercises:

4. Writing and testing FORTRAN programs for Interpolation and inverse interpolation using Lagrange's formula.
5. Writing and testing FORTRAN programs for Numerical integration using Simpson's $1/3^{rd}$ rule.
6. Writing and testing FORTRAN programs for solving ordinary differential equations.

Laboratory Tutorial

Discussion of techniques of actual numerical computation, program writing concepts, error analysis to supplement actual exercise given for numerical analysis and computer programming.

Group B: List of Experiments (6 hours/ week)

Specialization: Theoretical Physics

Numerical Analysis Exercises:

1. Curve fitting by least square method.
2. Obtaining eigenvalue and eigenvectors of a square matrix using Jacobi method.
3. Solving a system of linear equations using matrix inversion with LU decomposition.

FORTRAN Programming Exercises:

4. FORTRAN-program for curve fitting by least square method.
5. FORTRAN-program for obtaining eigenvalue and eigenvectors of a square matrix using Jacobi method.
6. FORTRAN-program for solving a system of linear equations using matrix inversion with LU decomposition.

C Programming Exercises:

7. C-program for curve fitting by least square method.
8. C-program for obtaining eigenvalue and eigenvectors of a square matrix using Jacobi method.
9. C-program for solving a system of linear equations using matrix inversion with LU decomposition.

Physics Simulation Exercises:

10. Numerical simulation of simple harmonic oscillator, anharmonic oscillator.
11. Numerical simulation of projectile with and without air resistance.
12. Use of spreadsheet for solving numerical and physics problems.

M. Sc.- (Physics)- Semester - III
(Specialization: Nuclear Physics)

PH (N)-533 -Nuclear Radiation Detection and Accelerators

Module I: Nuclear Radiation Detectors

Unit 1 Ionizing radiations: ionization and transport phenomena in gases – Avalanche multiplication. Detector Properties: Detection – Energy measurement – Position measurement - Time measurement.

Unit 2 Gas Counters: Ionization chambers, - Proportional counters – Multiwire proportional counters –Geiger – Muller counters – Neutron detectors.
Solid State Detectors: Semiconductor detectors - Integrating solid state devices – Surface barrier detectors.
Scintillation counters: Organic and inorganic scintillators - Theory, characteristics and detection efficiency.

Unit 3 High Energy Particle Detectors: General principles – Nuclear emulsions – Cloud chambers –Bubble chambers – Cherenkov counter.
Nuclear Electronics : Analog and digital pulses – Signal pulses – Transient effects in an R-C circuit – Pulse shaping – Linear amplifiers – Pulse height discriminators – Single channel analyser – Multi-channel analyser.

Module II : Accelerators

Unit 4 Historical Developments: Different type of accelerators – Layout and components of accelerators– Accelerators applications.

Unit 5 Transverse motion: Hamiltonian for Particle motion in accelerators – Hamiltonian in Frenet –Serret coordinate system – Magnetic field in Frenet – Serret coordinate system – Equation of betatron motion – Particle motion in dipole and quadrupole magnets – Linear betatron motion: Transfer matrix and stability of betatron motion – Courant-Snyder invariant and emittance-Stability of betatron motion-Sympletic condition – Effect of space – Charge force on betatronmotion.
Synchrotron Motion: Longitudinal equation of motion– The synchrotron Hamiltonian – The synchrotron mapping equation – Evolution of synchrotron phase Space ellipse.

Unit 6 Linear Accelerators: Historical milestones – Fundamental properties of accelerating structures –Particle acceleration by EM waves – Longitudinal particle dynamics in Linac – Transverse beam dynamic in a Linac.
Principle and Design Details of Accelerators: Basic principle and design details of accelerators viz, electrostatic, electrodynamics, resonant with special emphasis on Microtron, Pelletron and
their applications.

Text and Reference Books

1. H. A. Enge, Introduction to Nuclear Physics, Addison – Wesley, (1975.)
2. S. S. Kapoor and V.S. Ramamurthy, Nuclear Radiation Detectors, Wiley – Eastern, New Delhi, (1986).
3. W. H. Tait, Radiation Detection, Butterworth, London, (1980).
4. W. J. Price, Nuclear Radiation Detection, McGraw Hill, New York, (1964).
5. S. Y. Lee, Accelerator Physics, World Scientific, Singapore, (1999).
6. J. J. Livingood, Principles of Cyclic Particle Accelerators, D. Van Nostrand Co. (1961).
7. J. P. Blewett, Particle Accelerators, McGraw – Hill Book Co. (1962).
8. S. P. Kapita and V.N. Melekhin, The Microtron, Harwood Academic Publishers.
9. W. Scharf, Particle Accelerators and Their Uses, Harwood Academic Publishers. (1986).
10. I. M. Kapchinesky, Theory of Resonance Linear Accelerators, Harwood Academic Publishers. (1985).
11. P. Lapostole and A. Septier, Linear Accelerators, North Holland. (1970)

Theory Tutorials
PH (N)-533 (Nuclear Radiation Detection and Accelerators)
(Discussion and problem solving/exercise sessions)

1. Internal Conversion Electrons, Auger Electrons.
2. Energy Spectra of α, β, nd γ radiations.
3. Interaction of Radiation with Matter: Photoelectric Effect, Compton Scattering, Pair Production.
4. Calculation of Detector Efficiency and Resolution.
5. Pulse Height Spectrometry, Pulse Shape Discrimination.
6. Dead – Time Measurement.
7. Gas Quenching.
8. Mass Attenuation Coefficient as a Function of Photon Energy for Sodium iodide.
9. Effect of RC time constant on Pulse Shape. Necessity for High Energy Accelerators Classification of Accelerators
10. Layout and Components of Accelerators
11. Derivation of Betatron Equations of Motion
12. Courant – Snyder Parameterization
13. Experimental Tracking of Synchrotron Motion
14. EM Waves in Cylindrical Wave Guide
15. EM Waves in Cylindrical Pillbox Cavity
16. Design of a Cyclotron for a Given Energy of Protons

In addition to above, the tutorial will also consist of solving problems given in the Text and

M. Sc. (Physics): Semester-III

Specialization: Nuclear Physics

PH (N)-534 (Nuclear Reactions, Nuclear Energy and Nuclear Reactor Theory)

Module I : Nuclear Reactions and Nuclear Energy

Unit 1 Nuclear Reactions : Elementary approach to potential theory – S-wave neutron scattering in the compound nuclear reaction model – Derivation and discussion of Breit-Wigner resonance formula – Single level single channel R-matrix (R-function) theory.
Statistical Model of compound nuclear reaction – Pre-equilibrium reactions.
Discussion of direct reactions –- Stripping in zero range approximation – Spectroscopic factor and determination of nuclear level properties – Single nucleon transfer reactions- theory of average cross sections – Properties of optical potentials.

Unit 2 Heavy-ion collisions – Features of medium and low energy heavy–ion elastic scattering – deep inelastic scattering- fusion.
Diffraction models – Nuclear fission and extended liquid drop model.

Unit 3 Nuclear Energy: The Fission process-Neutrons released in the fission process Cross sections – The fission reactions – Fusion – Thermonuclear reactions – Energy production in stars.

Module II: Nuclear Reactor Theory

Unit 4 Introduction: Fundamentals of nuclear fission – Fission fuels – Neutron chain reaction – Multiplication factor – Condition for critically – Breeding phenomena – Different types of reactors – Fusion – Nuclear fusion in stars.
The Diffusion of Neutrons: Neutrons current density – The equation of continuity – Fick's law – The diffusion equation – Boundary conditions – Measurement of diffusion parameters.

Unit 5 Neutron Moderation: Moderation without absorption – Energy loss in elastic collisions – Collision and slowing–down densities – Moderation – Space dependent slowing down – Fermi's age theory – Moderation with absorption – NR and NRIM approximations – Temperature effects on resonance absorption.
Criticality: Criticality of an infinite homogeneous reactor – The one – region finite thermal reactor – The critical equation – Optimum reactor shapes – Multi-region Reactors – One group and two group methods of calculation of criticality – Reflector savings – Critical reactor parameters and their experimental determination.

Unit 6 Reactor Kinetics: Infinite reactor with and without delayed neutrons – The stable period – Reactivity and its determination – The Prompt jump and prompt critical condition – Charges in reactivity – Temperature coefficients – Fuel depletion effects.
Reactor Control: Control – rod worth – One control rod – Modified one group and two – group theories.

Text and Reference Books

Satchler, Introduction to Nuclear Reactions. (1990)

H.A. Enge, Introduction to Nuclear Physics, Addison – Wesley, (1975)

B.L. Cohenm Cocepts of Nuclear Physics, Tata Me Graw Hill, New Delhi,(1978).

P. Marmier and E. Sheldon, Physics of Nuclei and Particles, Vol.I & II Academic Press,(1969).

J.R. Lamarsh, Introduction to Nuclear Reactor Theory, Addison Wesley,(1966)

P.F. Zweifel, Reactor Physics, McGraw Hill Kogakusha Ltd., Tokyo,(1973).

S. Glasstone and M.C. Ediund, The Elements of Nuclear Reactor Theory, Van Nostrand Co.,(1953).

A.M. Weinberg and E.P. Winger, The Physical Theory of Neutron Chain Reactors, University of Chicago Press,(1958).

Theory Tutorials
PH (N)-534 (Nuclear Reactions, Nuclear Energy and Nuclear Reactor Theory)
(Discussion and problem solving/exercise sessions)

1. The Q-Equation
2. Conservation of Energy and momentum in Nuclear Reactions
3. Threshold Energies
4. Reaction Theory
5. Cross sections in Matrix Formalism
6. Calculation of Absolute Cross Section
7. Calculation of Excitation Energy
8. Resonance Reactions
9. Thermal Neutron Cross Sections
10. Diffusion Equation in Plane, Spherical and Cylindrical Geometries
11. Critically Calculations
12. Special Functions of Reactor Physics
13. The Reactor Transfer Function
14. Numerical Solution of the Multigroups Equation
15. The Collisions Kernel
16. Reactor Stability Analysis

M. Sc. (Physics): Semester-III

PH(T)-535 (Practicals)

(Specialization: Nuclear Physics)

Group-A Experiments

Note:

Practical consist of experiments in two groups **A** and **B**.

Group **A** experiments are common for all the specializations.

Group **B** experiments are different for different specializations.

Group A: List of Experiment **(3 hours/ week + 1 hour/week tutorial)**

Numerical Analysis Exercises:

1. Interpolation and inverse interpolation using Lagrange's formula.
2. Numerical integration using Simpson's $1/3^{rd}$ rule.
3. Solving ordinary differential equations using Runge-Kutta method.

FORTRAN Programming Exercises:

4. Writing and testing FORTRAN programs for Interpolation and inverse interpolation using Lagrange's formula.
5. Writing and testing FORTRAN programs for Numerical integration using Simpson's $1/3^{rd}$ rule.
6. Writing and testing FORTRAN programs for solving ordinary differential equations.

Laboratory Tutorial

Discussion of techniques of actual numerical computation, program writing concepts, error analysis to supplement actual exercise given for numerical analysis and computer programming.

Group B: List of Experiments **(6 hours/ week)**

Specialization: Nuclear Physics

1 To determine the efficiency of a GM counter using gamma source and also verify the inverse square law gamma & β - sources.
2 To study the pulse height spectra and the resolution of a NaI Scintillation Detector (Cs137, Co60, Mn54, Co57, Ba133).
3 Study of the energy calibration of NaI Scintillation Detector and to determine the energy of unknown source.
4 To determine the Linear Absorption co-efficient of gamma rays using NaI Scintillation Detector and establish the relation between energy and linear absorption coefficient.
5 To study the Compton scattering using NaI (TI) detector.
6 Study of Feather analysis of GM counter.
7 Range of alpha particles (Am-241) in air and polymer using alpha detector
8 Determination of activity of a gamma source using NaI (Tl) detector.
9 Study of backscattering of beta particle using GM counter with different materials.
10 Analysis of efficiency spectrum of Ge detector using ^{152}Eu standard source.

11 To design built and test high pass filter (2nd order) using Op-Amp.
12 To design built and test low pass filter (2nd order) using Op-Amp.
13 To study the transistor coincident circuit

Text and Reference books

1. S. S. Kapoor and V.S. Ramamurthy, Nuclear Radiation Detectors, Wiley Eastern Ltd., New Delhi,(1986).
2. R. M. Singru, Introduction to Experimental Nuclear Physics, John Wiley & Sons,(1974).
3. Alpha, Beta and gamma Ray Spectroscopy, K. Siegbahn, North -Holland, Amsterdam,(1965).
4. W. H. Tait, Radiation Detection, Butterworth, London, (1980).

K. Sriram and Y.R. Waghmare, Introduction to Nuclear Science and Technology, A. M. Wheeler, (1991).

Syllabus

OF

Course Work

for

MASTER OF SCIENCE (M.Sc.)

PHYSICS

Choice Based Credit System (CBCS)

DEPARTMENT OF PHYSICS,
VEER NARMAD SOUTH GUJARAT UNIVERSITY,
UDHANA MAGDALLA ROAD,
SURAT -395007. (GUJARAT)

Structure for M.Sc. Syllabus

Effective from June 2018

SEMESTER- IV

M.Sc. (PHYSICS)

Sr. No.	Course Code	Course Title	L	T	Cr.
	PH-541	Physics of Lasers & Lasers Applications	4	1	4
	PH-542	Atomic and Molecular Physics	4	1	4
	PH-(E)-543	Micro Electronics	4	1	4
	PH-(E)-544	Electronic Communication	4	1	4
	PH-(M)-543	Properties of Materials	4	1	4
	PH-(M)-544	Techniques of Materials Science	4	1	4
	PH-(T)-543	Advanced Quantum Mechanics	4	1	4
	PH-(T)-544	Group Theory and Quantum Field Theory	4	1	4
	PH-(N)-543	Nucleon-Nucleon Interaction and Nuclear Models	4	1	4
	PH-(N)-544	Strong, Weak and Electro Magnetic Interaction and QCD and Quark-Gluon Plasma	4	1	4
	PH-(C)-545	Practicals (Common)	9	1	8
	PH-(E)-545	Project (Electronics)	9	1	8
	PH-(M)-545	Project (Materials Science)	9	1	8
	PH-(T)-545	Project (Theoretical Physics)	9	1	8
	PH-(N)-545	Project (Nuclear Physics)	9	1	8
			25	05	24

Faculty Code: **Science** **Subject Code**: **PH** Level Code: **05**

Name of Program**: M.Sc.** Subject: **PHYSICS**

External Examination Time Duration: **03 Hours**

Name of Exam	Semester	PAPER No.	Course Group	Credit	Internal Marks	External Marks	Total Marks
M.Sc.	4	PH-541	Core	04	30	70	100
		PH-542	Core	04	30	70	100
		PH-543	Elective	04	30	70	100
		PH-544	Elective	04	30	70	100
		PH-545	Practicals and Project	08	60	140	200

Faculty of Science **M.Sc. PHYSICS**

DEPARTMENT OF PHYSICS, VEER NARMAD SOUTH GUJARAT UNIVERSITY, SURAT -395007

M. Sc. (Physics): Semester-IV

PH- 541: Physics of Lasers and Lasers Applications

Unit 1 LASER: Introduction, Einstein coefficients, Population inversion, Methods of population inversion, Threshold conditions, Laser rate equations: Two, three & four level systems, Variation of Laser power around threshold, Optimum output coupling.

Unit 2 Optical Resonators: Modes of a rectangular cavity and open planar resonator, Quality factor, Ultimate line width of the laser, Transverse & longitudinal mode selection, Q- switching, Techniques and for Q- switching, Mode locking in lasers, Techniques for mode locking.

Unit 3 Properties of laser beams and types of lasers: Coherence properties of laser light, Temporal Coherence, Spatial Coherence, Directionality, Ruby laser, Neodymium lasers (Nd: YAG & Nd: Glass) He- Ne laser, CO_2 laser, Argon ion laser, Dye laser, Semiconductor lasers.

Unit 4 Non-linear optics: Introduction, Second harmonic generation, Phase matching, Third harmonic generation, Optical mixing, Parametric generation light, self focusing of light, Multiphoton process: Multiquantum Photoelectric effect, Two photon processes, Theory of two photon processes, Experiments in two photon processes, Three photon processes, SHG & parametric generation of light in three photon process, Parametric light oscillator, Frequency up conversion, Phase conjugate optics.

Unit 5 Laser Spectroscopy: Rayleigh and Raman scattering, Stimulated Raman effect, Hyper- Raman effect Classical and Quantum mechanical treatment, Coherent anti stokes Raman Scattering, Spin Flip Raman laser, Free- electron laser, photo-acoustic Raman spectroscopy, Brillouin Scattering, Saturation Absorption spectroscopy, Doppler free two Photon spectroscopy.

Unit 6 Applications of LASER: Modulation Methods, Communications, Applications Using Focused Laser Radiation, Medical applications, Coherent Light Image And Data Processing, Holography, Photorefractive Holographic Recording, Laser For Fusion, Laser Cooling, Integrated Optics, Quantum Interference and Lasing Without Inversion.

Recommended Books:

1. Optical Electronics: A. K. Ghatak and K. Thyagarajan, Cambridge university press, (1990)
2. Lasers and Non – linear optics : B. B. Laud, Wiley Eastern Limited, (1992)
3. Introduction to Fiber Optics : Ajay Ghatak & K. Thyagarajan, Cambridge university press, (1999)
4. Principles of Lasers : Orazio svelto & David C. Hanna, Plenum Press- New York and London (1982)
5. Lasers and non linear optics: G. D. Baruha, Pragati Prakadhan, (2009)

Theory Tutorial

PH- 541: Physics of Laser and Lasers Applications

(Discussion and problem solving/exercise sessions)

1. Applications of laser in pure & applied sciences.
2. Chemical lasers
3. Non- liners effects in Fibers
4. Kerr effect
5. Fourier transforms & Optical application
6. Coherence & stellar interferometry.
7. Components of a lightwave communication system:Optical fiber
8. Modulators & Dectectors of a lightwave communication system.

M.Sc. (Physics): Semester-IV

PH-542 : Atomic and Molecular Physics

Unit 1 **One electron Atoms**

One-electron atoms, The Schrödinger equation and its solution, energy-levels and Eigen- -Functions, special hydrogenic systems, interaction of one-electron atoms with electromagnetic radiation, the dipole selection rules. Einstein coefficients, selection rules, Fine structure of hydrogenic atoms The Lamb shift and its determination, Hyperfine structure and isotopic shifts, The Stark effect, The Zeeman effect in strong and weak fields

Unit 2 **Two-electron atoms**

Schrödinger equation for Two-electron atoms - the role of Pauli exclusion principle, Energy levels of He atom. Level Scheme of two-electron atom, independent particle model, ground and excited states

Unit 3 **Many electron atoms**

The central field Approximation, The Thomas-Fermi model, The Hatree-fock method, Correction to the central field approximation, correlation effects , L-S coupling and j-j coupling. Many electron atom in an electromagnetic field, Selection rules for electric dipole transition, Retardation effects, magnetic dipole, electric quadrupole transitions

Unit 4 **Molecular Structure**

Born-Oppenheimer approximation - rotational, vibrational and electronics energy levels of dyatomic molecules, The electronic spin and Hund's cases, the structure of polyatomic molecules.

Unit 5 **Molecular Spectra**

Molecular spectra, Rotational spectra, vibrational-rotational and electronic spectra of diatomic molecules, Spin –dependent interaction and electric dipole transition, The Nuclear spin, The inverse spectrum of Ammonia

Unit 6 **Applications**

Magnetic resonance, Atom optics, Atoms in cavities and ions in traps, atomic clocks

Recommended Books

1. Physics of Atoms and Molecules by Bransden and Joachain, Pearson Education, 2nd Ed. (2004).
2. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by Eisberg and Resnick, John Wiley and Sons, 2nd Ed. (1985)
3. Fundamentals of molecular spectroscopy, C.N. Banwell, Tata McGraw-Hill, 3rd ed. (1983).
4. Molecular structure and spectroscopy, G. Aruldhas, Prentice Hall of India 2nd ed. (2002)

Theory Tutorials

PH – 542: Atomic and Molecular Physics

(Discussion and problem solving/exercise sessions)

1. Classical scattering by central problem
2. Angular momentum useful formula and results
3. Write all possible term symbol for the following electron configuration [He] 2s 2p
4. Write all possible term symbol for the following electron configuration [Be] 2p3d
5. Write all possible term symbol for the following electron configuration [Be] 2p2d
6. Helium atom has two forms ortho helium and para helium, Explain why ortho helium is metastable?

In addition to above the tutorial will also consist of solving problems given in the text and reference books.

M. Sc. (Physics): Semester-IV

(Specialization: Electronics)

PH(E)-543 MICRO ELECTRONICS

Unit 1 Classification of Semiconductor Devices, The enhancement MOSFET, The enhancement MOSFET Volt-Ampere characteristics, Early effect, MOSFET Circuit Symbols, The MOSFET as a Resistance, MOSFET as an Analog Switch, NMOS amplifier, Small Signal analysis of MOSFET.

Unit 2 Complementary MOS devices, BIFET, BIMOS and BICMOS Circuits, Three Stage operational Amplifiers, other types of operational Amplifiers, MOS operational Amplifiers. Current Source, The Widlar Current Source, Three Transistors Current Sources.

Unit 3 The NMOS Inverter, Propagation Delay of on NMOS Inverter, NMOS Logic Gates, The CMOS Inverter, CMOS Logic Gates, Emitter-coupled Logic (ECL) Circuit, Architecture of Complete ECL Circuit, Advantages and Limitations of ECL Circuit, Comparison of Logic families.

Unit 4 Classification of Solid State Memory devices, Limitations of Read Only Memory (ROM), Programmable ROMS(PROMS), Erasable PROMS, FAMOS, Programmable Array Logic (PAL), Programmable Logic Arrays (PLA).

Unit 5 Very Large Scale Integrated Systems (VLSI), Dynamic MOS Shift registers, Ratioless shift Register stages. CMOS Domino Logic, Charge Coupled Devices (CCD), CCD structures, Integrated Injection Logic (I^2L), Microprocessor and Microcomputers.

Unit 6 High Frequency Response of Common-Emitter stage, The Common-Source Stage at High Frequency, The time-constant Method of obtaining the Response, General Analysis of Multistage Feedback Amplifiers, Multiloop Feedback Amplifiers, Effect of Feedback on Bandwidth, Stability, Test of Stability.

Recommended Books:

1. Microelectronics, J. Millman and A. Grable, McGraw Hill, (1987).
2. Microelectronics Circuits, A. S. Sedra & K. C. Smith, Holt-Saunders, Japan,(1991).
3. Microelectronics- An Integrated Approach, Roger T. Howe, Charls G. Sodini. Pearson Education, Prentice Hall, First Edition, (2006).
4. Microelectronics Devices, Dipnakar Nagchoudhuri, Pearson Education, Prentice Hall, Second Edition, (2002).
5. Electronics Devices and Circuit Theory, Robert Boylestad and Louis Nashelesky PHI - Prentice Hall of India Pvt. Ltd., Fifth Edition, (1994).

Theory Tutorials

PH(E)- 543:MICROELECTRONICS

(Discussion and problem solving/exercise sessions)

-BJT's and FET's.

-VLSI Circuits design concepts.

-Low Frequency & High Frequency response Models.

-Bode Diagrams.

-Operational Transfer Functions & Frequency Transfer Functions.

-IC based Electronics Instruments.

M.Sc. (PHYSICS): SEMESTER- IV

(Specialization: Electronics)

PH(E)- 544: Electronic Communication

Unit 1 **Review of General communication system**
Spectral analysis: Fourier series, Exponential form of Fourier series, Examples of Fourier series, Sampling function, Response of a linear system, Normalized power in a Fourier expansion, Power spectral density, Effect of transfer function on power spectral density, Fourier transform, Example of Fourier transform, Convolution, Convolution, Power & energy transfer through a network, Correlation between waveforms, Power & cross correlation, Autocorrelation, Autocorrelation of a periodic waveform, Autocorrelation of non-periodic waveform of finite energy

Unit 2 **Amplitude Modulation**
Frequency Translation, Frequency multiplexing, Practicality of antenna, Narrow banding, Method of frequency translation, Amplitude modulation-DSB: Demodulation, Multiplier modulator, Non linear modulator, Switching modulator, Demodulation of DSB-SC signal, Amplitude modulation, Sideband & carrier power, Generation of AM signal, Demodulation of AM signal, Amplitude modulation-SSB: Time domain representation of SSB signals, Generation of SSB signal, Demodulation of SSB-SC signals.

Unit 3 **Angle modulation**
Concept of instantaneous frequency, generalized concept of angle modulation, Narrow-band Angle modulation, Wideband FM (WBFM), Generation of FM waves: Indirect method of Armstrong, Direct generation, Demodulation of FM signals, Phase locked loop, Analysis of phase locked loop. Stereophonic FM broadcasting, Comparisons: Frequency & phase modulation, Frequency & Amplitude modulation,

Unit 4 **Noise and Noise in AM systems**
External & internal noise, Noise calculations, Noise figure, Noise temperature, Noise in Amplitude modulation system: Advantage of super-heterodyne principle: Single channel, SSB-SC, DSB-SC, Envelope demodulator.

Unit 5 **Noise in FM systems**
Calculation of output signal & noise powers, Pre-emphasis & de-emphasis: Single Channel, Pre-emphasis & de-emphasis in commercial FM broadcasting.
Sampling theorem: low pass signals, Pulse amplitude modulation, Other forms of pulse modulation, Time division multiplexing, Bandwidth required for transmission of PAM signals, Comparison of FDM & TDM systems.

Unit 6 **Quantization of signals**
Quantization error, Pulse code modulation, PCM system, Companding & Differential PCM Delta modulation & Adaptive Delta modulation. Digital carrier schemes : FSK, PSK & DPSK.

Recommended Books:

1. H. Taub and D. L. Schilling Principles of communication systems, McGraw-Hill. (1986).
2. G. K. Mithal, Radio Engineering : Applied Electronics Vol. II (1987)
3. B. P. Lathi, Modern Digital & Analog communication systems, Prism Books Pvt. Ltd. (2011)
4. G. Kennedy, Electronic communication systems, McGraw-Hill, (2011)
5. J. G. Proakis and M. Salehi,, Fundamentals of communication systems: Pearson Education (2014).
6. D. Roddy and J. Coolem, Electronic communications, PHI (1995).
7. K. Samshanmugum, Digital and Analog communication systems, Johan Wiley & Sons (1979).

Theory Tutorials

PH(E)- 544: Electronic Communication

(Discussion and problem solving/exercise sessions)

1. Review of Fourier series and Fourier transform
2. Parseval's theorem
3. Introduction to modulation & demodulation
4. Normalized power
5. Comparison of FDM & TDM
6. Phase locked loop application
7. Natural & Flat-top sampling
8. Elements of a digital communication system source encoder / decoder, channel, modulator - demodulator & other functional blocks
9. Comparison of Analog & digital communication systems.

M. Sc. (Physics): Semester-IV

(Specialization : Electronics)

PH - 545 (Practical)

Note:

Practical consist of experiments in two groups **A** and **B**.

Group **A** experiments are common for all the specialization.

Group **B** Project work in their subject of specialization (based on syllabus).

Group A: List of Experiment **(3 hours/ week + 1 hour/week tutorial)**

C-Programming Exercises:

1. Writing and testing C-programs for Interpolation and inverse interpolation using Lagrange's formula.
2. Writing and testing C-programs for Numerical integration using Simpson's 1/3rd rule.
3. Writing and testing C-programs for solving ordinary differential equations.

Nuclear Physics Experiments:

4. Determination of plateau for Geiger-Müller tube and radiation absorption coefficient of a material.
5 Gamma ray spectrometer: calibration and finding gamma ray energy of a source.
6 Rutherford Scattering experiment.

Laboratory Tutorial

- Discussion of techniques of actual numerical computation, program writing concepts, error analysis to supplement actual exercise given for numerical analysis and computer programming.
- Construction and working of GM tube detector
- Principles behind gamma ray spectrometer.
- Alpha radioactive sources and detectors.

Group B: Project work in specialization field based on syllabus.

M.Sc. Physics Semester-IV

(Specialization: Materials Science)

PH(M)-543-Properties of Materials

Unit 1 Optical Properties of Materials, Electromagnetic wave propagation in solids, Reflection and Refraction at the interface Absorption and scattering.

Unit 2 Transparency, Translucency, Color, Florescence, Phosphorescence and Luminescence, NLO Properties, Ellipsometry.

Unit 3 Mechanical Properties of Materials Elastic, Inelastic and viscoelastic behavior, Plastic Deformation. The Tensile Stress-Strain curve. The Stress to move a Dislocation, Tension Test, Hardness, Fracture, Fracture Mechanics, Fatigue, Creep, Review of Strengthening Methods.

Unit 4 Electrical Conductivity, Band gap and Resistivity of material, Dielectrical Properties of material. Electrical Classification of Thermo couples, Piezoelectric material.

Unit 5 Insulating Properties of Materials High Resistivity Materials, Electron Mobility. Commercial Alloys, Insulation. Properties of Insulating.

Unit 6 Engineering Design Parameters for Selection of Materials, Environmental aspects of Material design, Industrial aspects of Materials design, Applications of advanced materials in Industries.

Recommended Books:

1. Material Science and Metallurgy –U. C. Jindal, Atish Mozumder Pearson - Dorling Kinderstey (India) Pvt. Ltd. 4^{th} Edition (2012).
2. Material Science and Metallurgy Parashiva murthy K.I. Pearson- Dorling Kindersely Pvt. Ltd. First Edition (2012).
3. Materials Science and Engineering – A First Course V. Raghavan. Prentice Hall of India – Pvt. Ltd. New Delhi 5^{th} Edition (2005).

Reference Books:

1. W. D. Caliseter, Materials Science & Engineering, John Wiley (1997)
2. A. G. Gay, Essentials of Materials Science, McGraw Hill (1976)
3. Manas Ghanda, Science of Engineering Materials, Vol. 1-3, MacMillan (1980)

Theory Tutorials
PH(M)-543 : PROPERTIES OF MATERIALS
(Discussion and problem solving/exercise sessions)

1. Magnetic Bubbles
2. Luminescence excitation & emission
3. Hardening & tempering of Steel
4. Importance of band gap in optical properties
5. Fundamentals of Materials
6. Materials and our Environment

M. Sc.- (Physics)- Semester – IV

(Specialization: Materials Science)

PH(M)-544: Techniques of Material Science

Unit 1 **Vacuum Science and Technology**

Introduction Vacuum, Brief History of Vacuum technology, Units of Vacuum, characteristics of vacuum, classification of vacuum ranges, applications of vacuum, vacuum system,

Unit 2 **Production and Measurement of Vacuum**

Classification of vacuum pumps, Rotary pumps, Roots pumps, Diffusion pumps. Molecular drag and turbo molecular pumps, Sorption pumps, cryogenic pump, Measurement of pumping speed, Constant pressure methods.

Classification of vacuum gauges, Mechanical gauges, Bourdon gauge, Pirani Gauge, Pennay Gauge Bayard-Alpart gauge, modified Ionization gauges.

Unit 3 **Preparation of Thin Film**

Physical methods: vacuum evaporation, Laser ablation. Epitaxial deposition, Molecular beam epitaxy,

Sputtering methods: Glow discharge, DC and RF Sputtering, Reactive Sputtering, Magnetron Sputtering, Ion plating, Ion beam deposition

Chemical methods: Electroplating, Thermal spray and detonation technology, plasma chemical vapor deposition (PCVD), Metal organic Chemical vapor deposition (MOCVD).

Unit 4 **Non-Destructive Testing**

Non-destructive testing: Basic test methods, leakage testing, penetrate method, magnetic methods, ultrasonic testing, radiography and applications, eddy current methods, recent developments in non-destructive testing holography, Non invasive diagnostic instrumentation, ultrasonic measurement, ultrasonic diagnosis.

Unit 5 **Phase Diagrams**

Phase diagrams, Solidification of O Metal in a Ingot Mould, Types of Phase diagrams, Development of Microstructures in Amorphous Alloy, No equilibrium cooling, Binary Eutectic Systems. Peritectic Reactions, Gibb's Phase rule.

Unit 6 **Phase Transformation**

Phase Transformation, Types of Phase transformation, Multiphase transformation Peritectic transformation, Bainite Transformation. Continuous Cooling transformation Curve.

Recommended Books :

1. Material Science and Metallurgy –U.C. Jindal, Atish Mozumder Pearson - Dorling Kinderstey (India) Pvt. Ltd. 4th Edition (2012).
2. Material Science and Metallurgy Parashiva murthy K.I. Pearson - Dorling Kindersely Pvt. Ltd. First Edition (2012).
3. Materials Science and Engineering – A First Course V. Raghavan. Prentce Hall of India – Pvt. Ltd., New Delhi 5th Edition (2005)
4. Vacuum Science and Technology V. V. Rao, T. B. Ghosh and K. L. Chopra Allied Publishers Limited (India) (1998).
5. Vacuum Technology, A. Roth, North-Holland, (1986).
6. "Handbook of Thin film technology" L. I. Maissel and R. I. Glang, Mc Graw Hill book Co. New york, (1970).
7. R. Hamshaw, Non-destructing Testing, Edward Arnokd, (1987).
8. Practical Non-destructive Testing Baldev Raj etc. Narosa Publishing House, (2009).

Theory Tutorials
PH(M)-544: Techniques of Materials Science
(Discussion and problem solving/exercise sessions)

1. Description of Gas state
2. Kinetic theory of gases
3. Maxwell-Boltzamann Velocity distribution
4. Transport of heat in gases and thermal conductivity
5. Evaporation Rate
6. Important equation in physics of ideal gases
7. Vacuum metallurgy
8. Non-destructive testing and Terminology
9. Evaluation of measurements; Uncertainty of measurments.

M. Sc. (Physics): Semester-IV

(Specialization : Materials Science)

PH - 545 (Practical)

Note:

Practical consist of experiments in two groups **A** and **B**.

Group **A** experiments are common for all the specialization.

Group **B** Project work in their subject of specialization (based on syllabus).

Group A: List of Experiment **(3 hours/ week + 1 hour/week tutorial)**

C-Programming Exercises:

1. Writing and testing C-programs for Interpolation and inverse interpolation using Lagrange's formula.
2. Writing and testing C-programs for Numerical integration using Simpson's 1/3rd rule.
3. Writing and testing C-programs for solving ordinary differential equations.

Nuclear Physics Experiments:

4. Determination of plateau for Geiger-Müller tube and radiation absorption coefficient of a material.
5 Gamma ray spectrometer: calibration and finding gamma ray energy of a source.
6 Rutherford Scattering experiment.

Laboratory Tutorial

- Discussion of techniques of actual numerical computation, program writing concepts, error analysis to supplement actual exercise given for numerical analysis and computer programming.
- Construction and working of GM tube detector
- Principles behind gamma ray spectrometer.
- Alpha radioactive sources and detectors.

Group B: Project work in specialization field based on syllabus.

M. Sc. (Physics): Semester-IV

(Specialization: Theoretical Physics)

PH-543: ADVANCED QUANTUM MECHANICS

Unit 1&2 **Relativistic equations in central potential**
Coupling of Klein-Gordon equation in electromagnetic field and its coupling to electromagnetic field, Klein-Gordon equation in a Coulomb field, Dirac particle in Electromagnetic fields, Dirac equation in a Coulomb field. Application of the Dirac equation to hydrogen-like atoms

Unit 3 **Symmetries**
Active and passive transformations, invariance and conservation laws, charge conjugation, time reversal invariance of the Dirac equation, helicity, chirality, vacuum polarization

Unit 4 & 5 **Relativistic Scattering Theory**
The non-relativistic propagator, propagator in positron theory, Scattering of spin ½ particle, Coulomb scattering of electrons, Coulomb scattering of positrons, Bremsstrahlung, Compton scattering, electron-electron scattering, electron-positron scattering, electron-positron pair annihilation into gamma rays

Unit 6 **Applications to Many-body Systems:**
Angular Momentum of a System of Identical Particles, Angular Momentum and Spin
One-Half Boson Operators, First-Order Perturbation Theory in Many-Body Systems,
The Hartree-Fock Method, Quantum Statistics and Thermodynamics

Recommended Books

1. Advanced Quantum Mechanics by Franz Schawbl Springer, 2nd Ed., (2009)
2. Relativistic Quantum Mechanics and Field Theory by Franz Gross, Wiley VCH, (1993)
3. Relativistic Quantum Mechanics by Armin Wachter, Springer, (2011)
4. Relativistic Quantum Mechanics by J. D. Bjorken and S. D. Drell (1964)
5. Advanced Quantum Mechanics by J. J. Sakurai, Pearson, (1967)

Theory Tutorials

PH – 543: ADVANCED QUANTUM MECHANICS
(Discussion and problem solving/exercise sessions)

1. Show Lorentz invariance of Klein-Gordon equation
2. Solution of Klein-Gordon equation for square-well potential
3. Solution of Klein-Gordon equation for exponential potential
4 Solution of Klein-Gordon equation for scalar 1/r potential
5. Eigenvalue spectrum of a Dirac particle in one dimensional square-well potential
6. Solution of the radial equations for a Dirac particle in a Coulomb potential
7. Klein paradox and the Hole theory

In addition to above the tutorial will also consist of solving problems given in the text and reference books.

M. Sc. (Physics): Semester-IV

Specialization: Theoretical Physics

PH (T)-544 (Group Theory and Quantum Field Theory)

Unit 1 Group axioms (postulates), examples of groups, conjugate elements and classes, subgroups, direct product of groups, isomorphism and homomorphism, permutation groups. Representations of a group, reducible and irreducible representations, Schur's lemmas (statement), Orthogonality theorem, characters of a representation, direct product of representation, representation of a direct product group.

Unit 2 Continuous groups: Topological groups and Lie groups, the axial rotation group SO(2), 3-dimentional rotation group SO(3), Lorentz group, special unitary group SU(2), generators of U(n), SU(n), Lie algebra and representation of a Lie group, special unitary group SU(3), physical applications of SU(2) and SU(3).

Unit 3 Review of Schrödinger equation, Klein-Gordon equation and Dirac equations. Introduction to Quantum theory of Fields, transition from discrete to continuous systems, Classical Field theory, choosing Lagrangian. Field quantization, a real scalar (KG) field, Yukawa potential, quantization of a real scalar field, vacuum state, the pion-nucleus interaction. Complex scalar field, charge scalar field. Free Dirac Field, quantization of a free Dirac field, Vector Mesons.

Unit 4 Radiation field and photons, gauge transformations, quantization of electromagnetic field. Electron-photon interaction. Covariant perturbation theory, S-matrix, U-matrix, scattering of electrons by an external field, normal product, time ordered products, propagators, contraction, covariant commutation relation, Feynman graphs: configuration-space rules, momentum-space rules, scattering of photons by an electron (Compton Scattering), electron-electron scattering, electron-muon scattering, electron-proton scattering. Higher order corrections, renormalization in quantum electrodynamics.

Unit 5 Gauge field theories, Abelian transformations U(1) gauge symmetry, local gauge transformation. Electrodynamics of a Dirac field, local and global gauge transformations, spontaneous breaking of global and local symmetry, Goldstone model, Higgs' mechanism, Non-Abelian transformations.

Unit 6 The Standard Model: Electroweak interaction, electroweak theory of leptons, neutral current, W and Z widths, weak quark mixing, neutral currents, Quantum Chromodynamics (QCD) and confinement, Quark-Gluon Plasma.

Recommended Books

1. A. W. Joshi, Group theory for physicists, New Age Publication (2005).
2. M. Hamermesh, Group theory and its application to physical problems, Addison-Wesley Pub Co., Inc (1962).
3. M. P. Khanna, Introduction to particle physics, PHI, (1990).
4. C. Itzykson and J.B. Zuber, Quantum Field Theory, McGraw Hill, (1980).
5. B.K. Agarwal, Quantum Mechanics and Field Theory, Asia, (1976).
6. I. J. R. Aitchison and A. J. R.Hey, Guage theories in Particle Physics, Adam Hilger (U.K.) (1992)
7. J. J. Sakurai, Advanced Quantum Mechanics, John Wiley (1967).

Theory Tutorials
PH(T)-544: Group Theory and Quantum Field Theory
(Discussion and problem solving/exercise sessions)

1. Schur's lemma (derivation, application).
2. Character table for C_{4v}, and C_{5v} groups.
3. Discussion about classical and quantum fields.
4. Derivation of four-dimensional Euler-Lagrange equation.
5. QED examples, Bhabha, Moller scattering, electron-muon scattering etc.
6. Examples for Euler-Lagrange equation.
7. For SU(2) matrices prove $e^{i\,\mathbf{r}.\boldsymbol{\sigma}} = \cos r + (\mathbf{r}.\boldsymbol{\sigma})\sin r$.
8. SU(2) isospin breaking effects.
9. SU(3) algebra in terms of quark fields.
10. Prove $D(p,q) = \frac{1}{2}(p+1)(q+1)(p+q+1)$ by different methods. Get different D(p,q) multiplets octet, decuplet etc.
11. Coupling of SU(2) vector representation for constructing SU(2) invariant πNN, $\rho\pi\pi$, $\omega\rho\pi$ coupling.
12. Taking doublet $\psi(\psi_1, \psi_2)$ show $S= \psi^+ \psi$, $V= \psi^+ \boldsymbol{\sigma} \psi$, ($\sigma$, Pauli matrices) as scalar and vectors under infinitesimal and finite rotations.
13. Application of SU(3) to particle physics.
14. SU(4) (extension of SU(3)) introduction.
15. GUT (introduction).
16. Basics of supersymmetry.
17. Running constants in QED, QCD.
18. Yang Mills field.
19. Higgs mechanism.
20. Evidence for color, QCD, standard model.

M. Sc. (Physics): Semester-IV

(Specialization: Theoretical Physics)

PH(T)-545 (Practical)

Note:

Practical consist of experiments in two groups **A** and **B**.

Group **A** experiments are common for all the specialization.

Group A: List of Experiment **(3 hours/ week + 1 hour/week tutorial)**

C-Programming Exercises:

1. Writing and testing C-programs for Interpolation and inverse interpolation using Lagrange's formula.
2. Writing and testing C-programs for Numerical integration using Simpson's 1/3rd rule.
3. Writing and testing C-programs for solving ordinary differential equations.

Nuclear Physics Experiments:

4. Determination of plateau for Geiger-Müller tube and radiation absorption coefficient of a material.
5 Gamma ray spectrometer: calibration and finding gamma ray energy of a source.
6 Rutherford Scattering experiment.

Laboratory Tutorial

- Discussion of techniques of actual numerical computation, program writing concepts, error analysis to supplement actual exercise given for numerical analysis and computer programming.
- Construction and working of GM tube detector
- Principles behind gamma ray spectrometer.
- Alpha radioactive sources and detectors.

.**Group B List of Experiments** **(6 hours/ week)**

Project Work involving complete study of a physics problem by simulation by writing FORTRAN / C / Mathematica program.

M. Sc. (Physics): Semester-IV

(Specialization: Nuclear Physics)

PH (N)-543 (The Nucleon–Nucleon Interaction and Nuclear Models)

Module I : The Nucleon–Nucleon Interaction

Unit 1 Nucleon – Nucleon Interaction and Hadron Structure: Phenomenological Nucleon-Nucleon Potentials – Meson theory – Derivation of Yukawa interaction – Electromagnetic properties of deuteron.

Unit 2 Polarization in nucleon – nucleon scattering – Scattering matrix – Probing charge distribution with electrons – Form factors – Proton form factors – Deep inelastic electron – proton scattering – Bjorken scaling and partons – Quarks within the proton – Gluons as mediators of strong interaction.

Unit 3 Particle Phenomenology: Pion – Nucleon scattering – isospin analysis – Phase shifts – Resonance and their quantum numbers – Production and formation experiments - Relativistic kinematics and invariants – Mandelstam variables – Phase space – Decay of one particle into three particles – Dalitz Plot.

Module II : Nuclear Models

Unit 4 Single Particle Shell Model: Determinantal wave function of the nucleus – single particle operator and their expectation values.

Unit 5 Extended Single Particle Model: Classification of shells – Seniority and reduced i–spin – Configuration mixing – Pairing force theory – Gap equation and ground state properties – Idea of quasi particles – Simple description of two – Particle shell model spectroscopy.

Unit 6 Collective Model of Nucleus: Deformable liquid drop and nuclear fission – Shell effects on liquid drop energy – Collective vibrations and excited states – Permanent deformation and collective rotation – Energy levels – Electromagnetic properties of even – even, odd-A deformed nuclei – Nilsson model and equilibrium deformation – Behavior of nuclei at high spin – Back bending.

Text and Reference Books:

P. Marmier and E. Sheldon, Physics of Nuclei and Particles, Vol. I and II, Acadamic Press, New York, (1970).

M. A. Preston and R. K. Bhaduri, Structure of the Nucleus, Addision Wesley, (1975).

R. R. Roy and B. P. Nigam, Nuclear Physics, Wiley- Eastern Ltd. (1983).

M. K. Pal, Theory of Nuclear Structure, Affiliated East West, Madras, (1982).

Greiner and Marukn, Nuclear Models, (1996)

Bertulani and Danielewzz, Introduction to Nuclear reactions, CRC press, (2014)

A. E. Henley and A. Garcia, Subatomic Physics, World Scientific, (2007)

Theory Tutorials

PH (N)-543 (The Nucleon–Nucleon Interaction and Nuclear Models)

(Discussion and problem solving/exercise sessions)

1. Scattering Matrix
2. Electromagnetic Form Factors of the Deuteron
3. Comparison Between Experimental p-p Scattering Phase Parameters Derived Form a Pion Exchange Potential.
4. Nucleon – Nucleon Scattering at Elevated Energies and its Interpretation.
5. Numerical Solutions to the Lippman – Schwinger Equation.
6. Relation between Various Sets of Invariants.
7. Nucleon – Nucleon Phase Shifts and Phenomenological Potentials.
8. Shell Model Configuration and Configuration Mixing
9. Spin – Orbit Coupling
10. Nuclear Ground State and Angular Momenta
11. Magnetic Moments and the Shell Model – Schmidt Lines
12. Anisotropic Harmonic Oscillator Potential
13. Coupling of Particle and Collective Motion – Weak and Strong Couplings
14. Comparison of Nuclear Models

M. Sc. (Physics): Semester-IV

(Specialization: Nuclear Physics)

PH (N)-544 (Strong, Weak and Electromagnetic Interaction and QCD and Quark-Gluon Plasma)

Module I : Strong, Weak and Electromagnetic interactions

Unit 1 & 2 Strong interactions and symmetries : Uses of symmetry – Space time and internal symmetries – Lie groups generations and Lie algebra – Casimir operators – SU(2) irreducible representation – Weight diagram – Diagonal generators – SU(3) generators – U and V spin - Raising and lowering operators – Root diagram – Weight diagram – Multiplets of SU(n) – Baryons and meson multiplets – Symmetry breaking – Gell-Mann-Okubo mass formula – Charm, Bottom and top quarks and higher symmetry – Bag Model for hadrons.

Unit 3 Weak and Electromagnetic Interactions : Invariance of Dirac equation – Bilinear covariants – Properties of gamma matrices – Leptonic, semi-Leptonic and non-Leptonic weak decays – Selection rule for Leptons – Current-current interaction and V-A theory – Universality – Abelian non-Abelian gauge invariance – Spontaneous symmetry breaking and Higgs mechanism – Standard model for electro weak unification.

Module II : QCD and Quark – Gluon Plasma

Unit 4 Perturbative QCD I : Color gauge invariance and QCD Lagrangian – Deep inelastic scattering: The GLAP equations – an alternative approach to the GLAP equation -
Common parameterizations of the distribution functions – Structure Functions - The spin – dependent structure functions and the MIT bag Model.

Unit 5 Perturbative QCD II: The Drell – Yan process – Small-x physics and the Gribov – Levin – Ryskin equation.

Unit 6 Nonperturbative QCD: QCD sum rules – The ground state of QCD – Equation of state of a Quark – Gluon Plasma – Hadronization Phase transition.

Text and Reference Books

1. F. Halzen and A. D. Martin, Quarks and Leptons, John – Wiley & Sons, New York, (1984).
2. G. Kane, Modern Elementary Particle Physics, Addison – Wesley, (1987).
3. D. B. Lichtenberg, Unitary Symmetry and Elementary Particles, 2nd Edition, Academic Press, (1978).
4. R.K. Bhaduri, Models of Nucleon, Addison – Wesley, Reading, MA, (1988).
5. J. McL. Emmerson, Symmetry Principles in Particle Physics, Clarendon Press, Oxford, (1972).
6. M. Leon, An introduction to Particle physics. Academic Press, New York, (1973).
7. I. J. R. Aitchison and A. J. G. Hey, Gauge Theories of Particle Physics, Adam Hilger, Bristol, (1989).
8. W. Greiner and A. Schafer, Quantum Chromodynamics, Springer, Berlin, (1993).
9. D.H. Perkins, Introduction to High Energy Physics, Addison – Wesley, London, IV Edition, (2000).
10. F. J. Yndurain, Quntum Chromodynamics – An Introduction to the Theory of Quarks and Gluons, Springer – Vertag, New York, (1983).

Theory Tutorials

PH (N)-544 (Strong, Weak and Electromagnetic Interaction and QCD and Quark-Gluon Plasma)

(Discussion and problem solving/exercise sessions)

1. The Hadron Spectrum
2. Algebra of Gamma Matrices
3. The Nucleonic Scattering Tensor with Weak Interaction
4. Higgs' Bosons and Spontaneous Symmetry Breaking
5. Gauge Invariance and Gauge Bosons
6. Lepton and Hadron Currents
7. Feynman Rules of QCD
8. Kinematics, Cross Sections and Decay Rates
9. The Renormalized Coupling Constant of QCD Asymptotic Freedom

M. Sc. (Physics): Semester-IV

(Specialization: Nuclear Physics)

PH(N)-545 Practical

Note:

Practical consist of experiments in two groups **A** and **B**.

Group **A** experiments are common for all the specialization.

Group **B** Project work in their subject of specialization (based on syllabus).

Group A: List of Experiment **(3 hours/ week + 1 hour/week tutorial)**

C-Programming Exercises:

1. Writing and testing C-programs for Interpolation and inverse interpolation using Lagrange's formula.
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3. Writing and testing C-programs for solving ordinary differential equations.

Nuclear Physics Experiments:

4. Determination of plateau for Geiger-Müller tube and radiation absorption coefficient of a material.
5 Gamma ray spectrometer: calibration and finding gamma ray energy of a source.
6 Rutherford Scattering experiment.

Laboratory Tutorial

- Discussion of techniques of actual numerical computation, program writing concepts, error analysis to supplement actual exercise given for numerical analysis and computer programming.
- Construction and working of GM tube detector
- Principles behind gamma ray spectrometer.
- Alpha radioactive sources and detectors.

Group B: Project work in specialization field based on syllabus.