NATIONAL INSTITUTE OF TECHNOLOGY SILCHAR
Department of Physics
Program: M. Sc in Applied Physics (w.e.f. 2019)
Course structure and detailed syllabus
Minimum Credit Requirement: 70
Minimum Duration: 4 semesters Maximum Duration: 6 semesters

Semester	Credit
I	16
II	18
III	17
IV	19

Semester-I

Course Code	Course Name	L	T	P	Credit
PH 5101	Mathematical Physics-I	3	0	0	3
PH 5102	Classical Mechanics	3	0	0	3
PH 5103	Quantum Mechanics-I	3	0	0	3
PH 5104	Electrodynamics-I	3	0	0	3
PH 5105	Physics Lab-I	0	0	6	4
Total Credits					16

Semester-II

Course Code	Course Name	L	T	P	Credit
PH 5106	Condensed Matter Physics-I	3	0	3	3
PH 5107	Statistical Mechanics	3	0	0	3
PH 5108	Quantum Mechanics-II	3	0	0	3
PH 5109	Mathematical Physics-II	3	0	0	3
PH 5110	Physics Lab-II	0	0	6	4
PH 5111	Computational Physics lab	0	0	3	2
Total Credits					18

Semester-III

Course Code	Course Name	L	T	P	Credit
PH 6112	Condensed matter Physics -II	3	0	0	3
PH 6113	Electrodynamics-II	3	0	0	3
PH 6114	Electronics	3	0	0	3
PH 6115	Atomic and Molecular Physics	3	0	0	3
PH 6116	Physics Lab-III	0	0	6	4
PH 6117	Seminar	0	0	2	1
Total Credits					17

Semester-IV

Course Code	Course Name	L	T	P	Credit
PH 6118	Physics of Semiconductor	3	0	0	3
PH 6119	Experimental Techniques	3	0	0	3
PH 6120	Nuclear and Particle Physics	3	0	0	3
PH 6199	Project	0	0	0	10
Total Credits					19

PH-5101: Mathematical Physics-I **L-3, T-0, P-0**

Matrices, Determinants, Matrix operations, linear combination, Linear function, linear operators, linear dependence and independence. Vector Spaces: Vectors in Function spaces, Operators, self adjoint operators, unitary operators, Transformation of operators, invariance, Gram-Schmidt orthogonalization.

Eigenvalues and eigenvectors of a matrix, Cayley-Hamilton theorem, diagonalization,

Tensor analysis - summation conventions, contra-variant and co-variant tensors and their transformations, classification and fundamental operations with tensors, line element & metric tensor

Special functions – Legendre, Hermite, Laguerre & Bessel functions, Rodrigues formula, Generating function, Recursion relations, Orthogonality relation

Fourier series expansion, Fourier series for arbitrary period, Gibbs phenomenon, Integral transformation – Fourier & Laplace transformation

References:

1. Mathematical Methods in the Physical Sciences by M.P.Boas
2. Advanced Engineering Mathematics by Kreyszig
3. Mathematical methods for physicists by Arfken and Weber
4. A first course on complex analysis by Zill
5. Schaum's outline Complex Variables by Spiegel
6. Methods of Mathematical Physics by Courant and Hilbert
7. Special functions and Polynomials by Gerard ‘t Hooft and Nobbenhuis

PH 5102: Classical Mechanics **L-3, T-0, P-0**

Mechanics of a System of Particles, Review of Lagrange's equation: D'Alembert's Priniciple, Lagrange's equations, applications, Variational calculus.

Reduction to the Equivalent one body problem, Equations of motion and first integrals, Classification of orbits, Motion under inverse square law-Kepler problem, Scattering in a central force field

Hamiltonian formulation: Legendre transformations and Hamilton equations of motion, cyclic coordinates and conservative theorems, Derivation of Hamilton's equations a variational principle, principle of least action.

The equations of Canonical transformations, Examples of Canonical transformations. Poisson brackets and other canonical invariants, Equations of motion, Hamilton-Jacobi theory for Hamilton's Principal function, The Harmonic Oscillator problem as an example of the Hamilton-Jacobi method, Hamilton-Jacobi equation for Hamilton's characteristic function Action-angle variables.

Theory of small oscillations, normal coordinates, normal modes, coupled oscillations.
This course is the basis for all advanced courses in theoretical physics.

References:

1. H. Goldstein, Classical Mechanics
2. L.O. Landau and E.M. Lifshitz, Mechanics.
3. I.C. Percival and D. Richards, Introduction to Dynamics
4. J.V. Jose and E.J. Saletan, Classical Dynamics: A Contemporary Approach

PH 5103: Quantum Mechanics-I **L-3, T-0, P-0**

Postulates of Quantum Mechanics, wavefunction, probability and probability current density, conservation of probability, Operators and their expectations values, Dirac notation.

Schroedinger equation: Simple potential problems, infinite potential well, step and barrier potentials, finite potential well and bound states, linear harmonic oscillator, operator algebra of harmonic oscillator; Three dimensional problems: spherical harmonics, free particle in a spherical cavity, central potential, Three dimensional harmonic oscillator, degeneracy, Hydrogen atom; Angular momentum: Commutation relations, spin angular momentum, Pauli matrices, raising and lowering operators, Total angular momentum, addition of angular momentum, Clebsch-Gordon coefficients.

The variational principle, the ground state of Helium, the hydrogen molecule ion.

References:

1. Introduction to Quantum Mechanics: D. J. Griffiths
2. Quantum Mechanics Concept and Applications: N. Zettili
3. Quantum Physics: S. Gasiorowicz
4. Modern Quantum Mechanics: J.J. Sakurai
5. Quantum Mechanics: L. I. Schiff

PH 5104: Electrodynamics-I **L-3, T-0, P-0**

Laplace equation in one, two and three dimensions. Boundary equation and uniqueness theorem, conductor and second uniqueness theorem. The method of Images: The classic Image problem, Induced surface charge, Force and energy and other image problems.

Electric Field in matter: Dielectric, Induced dipoles, Alignment of polar molecules, polarization, bound charges and its physical interpretation, the field inside a dielectric, Gauss law in the presence of dielectric, boundary conditions, Linear dielectric: susceptibility, permittivity dielectric constant boundary value problem with linear dielectric , energy and force in dielectric.

Review of Magnetostatics: magnetic vector potential and magneto static boundary conditions, multipole expansion of the vector potential.

Magnetic field in matter: Diamagnets, paramagnets, ferromagnets and torque and forces on magnetic dipoles, The field of magnetized object and bound currents the magnetic field inside matter, Linear and non-linear media.

Electrodynamics: Maxwell's equations: How Maxwell fixed Ampere's law, Magnetic charge, Maxwell's equation in matter, Boundary conditions, The continuity equation, Poynting's theorem, Momentum: Newton's Third law in Electrodynamics, Maxwell's stress Tensor, Conservation of momentum, angular momentum,.

References:

1. J. D. Jackson, Classical Electrodynamics, Wiley Eastern, 2nd Edition (1975).
2. David J. Griffiths, Introduction to Electrodynamics, Prentice Hall of India, 2nd Edition, (1989).

3. J.R. Reitz., F.J. Milford and R. W. Christy, Foundations of Electromagnetic Theory, 3rd Edition, Narosa Pub. House (1976).
4. P. Lorrain and D. Corson, Electromagnetic Fields and Waves. CBS Publishers and Distributors (1986).
5. B.H. Chirgwin, C. Plumpton and C. W. Kilmister, Elementary Electromagnetic Theory, Vols.1, 2 and 3" Pergamon Press (1972).

PH 5105: Physics-Lab-I **L-T-P: 0-0-6**

1. To calculate the beam divergence and spot size of the given laser beam
2. Determination of wavelength of unknown lines with help of plane transmission grating.
3. To draw the calibration curve (d vs λ) of a spectrometer with given prism and hence find the wavelength of some unknown lines.
4. To draw the current –voltage (I-V) characteristics of a solar cell.
5. To determine the permittivity of air using parallel plate capacitor.

PH 5106: Condensed Matter Physics-I **L-T-P : 3-0-0**

Crystal Physics; Symmetry, Bravais lattice, point and space groups, Miller indices and reciprocal lattice, Structure determination: diffraction, X-ray , electron and neutron, crystal binding.

Lattice Dynamics: Monoatomic and diatomic lattices. Phonon frequencies and density of states. Debye theory dispersion curves, thermal expansion. Thermal conductivity, Normal and Umklapp processes scattering experiments.

Free electron theory of metals. Thermal and transport properties, Hall effect, electronic specific heat. Bloch function Kronig Penney model, Brillion zones effective mass of charge carriers. Tight binding and Wigner Seitz method (Only qualitative).

Macroscopic electric field, local electric field at an atom, filed of dipoles inside cavity, Dielectric constant and polarizability: Complex dielectric constant and dielectric losses, electronic polarizability, classical theory,

References:

1. C. Kittel, Introduction to Solid State Physics, John Wiley (1996)
2. A. J. Dekker, Solid State Physics, Macmillan (1986)
3. N. W. Ashcroft and N D Mermin, Solid state Physics Cengage (1976)

PH 5107: Statistical Mechanics **L-T-P : 3-0-0**

Classical Statistical Mechanics: Statistical Thermodynamics: Macroscopic and microscopic states, connection between statistics and thermodynamics, classical ideal gas entropy of mixing and Gibb’s paradox, Elements of ensemble theory, Micro canonical, canonical and grand canonical ensembles, partition and grand partition function, particle density energy fluctuations in grand canonical ensemble, equivalence to other ensembles.

Quantum Statistical Mechanics: Basic principle, quantum mechanical ensemble theory, density matrix, ensemble in Quantum Statistical Mechanics.

Ideal bose gas: Thermodynamics, Bose-Einstein condensation, black body radiation, phonons, Helium-II

Ideal Fermi Gas: Thermodynamics, Pauli paramagnetism, Landau diamagnetism, thermionic and photoelectric emissions white dwarfs.

References:

1. R. K Pathria, Statistical Mechanics, Butterworth-Heinemann (1996)
2. K. Huang, Statistical mechanics, John Wiley Asia (2000)
3. W Greiner, L Neise, H Stocker, Thermodynamics and Statistical Mechanics, Springer (1994)
4. L D Landua and E M Lifshitz, Statistical Physics-I Pergamon (1980)

PH 5108: Quantum Mechanics-II **L-T-P: 3-0-0**

Time independent perturbation theory - nondegenerate and degenerate cases, Fine structure of hydrogen – relativistic correction, spin-orbit coupling, Zeeman effect – weak, strong and intermediate-field, hyperfine splitting in hydrogen, Stark effect.

WKB approximation – classical region, quantization condition, tunneling, Gamow's theory of α-decay, connection formulas

Three pictures of quantum mechanics, time dependent perturbation theory – two-level systems, sinusoidal perturbations, semi-classical treatment for interaction of radiation with matter, Fermi's golden rule, magnetic resonance, Adiabatic and sudden approximation.

Scattering – classical theory, quantum scattering theory, partial wave analysis – phase shifts, Born approximation – integral form of Schrödinger equation, scattering for different kind of potentials

Introduction to relativistic quantum mechanics, Klein-Gordon & Dirac equation and their solutions

References:

1. D. J. Griffiths, *Introduction to Quantum Mechanics*.
2. L. I. Schiff, *Quantum Mechanics*.
3. B. H. Bransden& C. J. Joachain, *Quantum Mechanics*.
4. R. Shankar, *Principles of Quantum Mechanics*.
5. L. D. Landau and E. M. Lifshitz, *Quantum Mechanics, Volume 3*.
6. N. Zettili, *Quantum Mechanics.*
7. J. J. Sakurai, *Modern Quantum Mechanics.*
8. J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics.*

PH 5109: Mathematical Physics-II **L-T-P: 3-0-0**

Complex analysis - complex number system, complex variables, complex functions, complex function as mapping, linear mapping: translation, rotation and magnification, limits, continuity, derivative, analytic functions, Cauchy-Riemann equations, Complex integration, Cauchy-Goursat's theorem, Cauchy Integral formulas, Sequences and infinite series, Poles – classification and Residue theorem.

Polynomial equation, Linear equation and Eigen value problem, Interpolation and approximation, Differentiation and Integration.

References:

1. Mathematical Methods in the Physical Sciences by M. P. Boas
2. Advanced Engineering Mathematics by Kreyszig
3.Mathematical methods for physicists by Arfken and Weber
4. A first course on complex analysis by Zill
5. Schaum's outline Complex Variables by Spiegel
6. Methods of Mathematical Physics by Courant and Hilbert
7. Numerical Recipes in C, W. H. Press, S. A. Teukolsky, W. T. Verlling and B. P. Flannery
8. Numerical Methods for Scientific and Engineering Computation, M K Jain, S R K Iyengar R K Jain

PH 5110: Physics Lab-II **L-T-P: -0-0-6**

1. To determine charge density of a semiconductor using Hall effect.
2. To determine the wavelength Laser beam using Michelson interferometer.
3. To measure the magnetresistance of n-type semiconductor
4. To measure the susceptibility of liquid or aqueous solution using Quinck's method.
5. To study the basics principle of digital to analog converter.
6. To study the lattice dynamics of monatomic and diatomic linear chain using lattice dynamics Kit.

PH 5111 Computational Physics Lab **L-T-P: -0-0-3**

Numerical Differentiation: forward, backward and centred difference formulae;

Numerical integration: Trapezoidal and Simpson's rule, Gauss-Legendre integration, applications; Linear equation and eigen value problem

Students will be able to:

At the end of this laboratory, the students will be capable to use different numerical scheme to tackle basic physical problems using C/FORTRAN.

References

1. Numerical Recipes in C, W. H. Press, S. A. Teukolsky, W. T. Verlling and B. P. Flannery
2. Numerical Methods for Scientific and Engineering Computation, M K Jain, S R K Iyengar R K Jain

PH-6112: Condensed Matter Physics-II **L-T-P: 3-0-0**

Superconductivity: Experimental survey (zero resistance, persistent currents, superconducting transition temperature (T_c) and critical field (H_c), isotope effect, perfect diamagnetism and Meissner effect, heat capacity, energy gap and microwave properties); Theoretical survey (thermodynamics of superconductors, free energy, London equation, penetration depth, coherence length, BCS theory of superconductivity, Cooper pairing and properties of BCS ground states, flux quantization); Ginzburg-Landau theory; Tunneling phenomenon, energy-level diagram, DC and AC Josephson effects, microscopic quantum interference, Type-I and type-II superconductors, intermediate states, mixed states. Basics of High-T_c superconductivity.

Magnetism: Magnetic moments and Bohr magnetron, magnetic field in free space and mater, canonical momentum, Atoms in a magnetic field; Isolated magnetic moments: Magnetic susceptibility; Langevin's theory of diamagnetism and paramagnetism (semi-classical treatment), Brillouin function; Van-Vleck and Pauli spin paramagnetism, ground state of an ions and Hund's rule; Crystal field splitting; quenching of orbital angular momentum; Electron spin resonance (ESR), Nuclear magnetic resonance (NMR); Spin-lattice and spin-spin relaxation, Ferromagnetism: Weiss theory of ferromagnetism; Exchange interaction; Heisenberg model, Ferromagnetic domains, Magnetization curve; Bloch wall, Curie and Neel temperature; Spin waves and magnon dispersion relation; The Bloch $T^{3/2}$ law; Antiferromagnetism and Ferrimagnetism, Magnons in Antiferromagnet

Phase Transitions and critical Phenomena: Order parameter; Critical points; First and second order phase transitions; Phase diagram; Mean field theory; Properties near critical point; Landau theory of phase transition; Landau-Ginzberg theory; Bragg-Williams theory

References

1. Magnetism in Condensed Matter (Oxford master series in Condensed matter Physics) by Stephen Blundell

2. Introduction to Soild State Phsyics, Wiley, Charles Kittel

3. Solid State Physics by N. David, Cornell University, Neil W. Ashcroft

4. Condensed Matter Physics, Wiley, Michael P. Mardar

5. Introduction to phase transitions and Critical Phenomena (OUP), by H. Eugene Stanley

PH 6113: Electrodynamics-II **L-T-P: 3-0-0**

Electromagnetic Waves: The wave equation, Sinusoidal waves, Boundary conditions: reflection and transmission, Polarization. Electromagnetic waves in vacuum, The wave equation for **E** and **B**, Monochromatic Plane waves, Energy and momentum in electromagnetic waves.
Electromagnetic waves in matter, Propagation in linear media, reflection and transmission at normal incidence. Reflection and transmission at oblique incidence
Absorption and dispersion, Electromagnetic waves in conductors, reflection at a conducting surface, the frequency dependence of permittivity, Wave guides, the waves in a rectangular wave guide, the coaxial transmission line.

Potentials and fields: Scalar and vector potentials, Gauge transformations, Coulomb Gauge and Lorentz Gauge. Retarded potentials, Jefimenko's equations.LienardWiechert potentials, The field of a moving point charge.

Radiation: What is radiation? Electric dipole radiation, Magnetic dipole radiation, radiation from an arbitrary source.Power radiated by a point charge, radiation reaction, the physical basis of the radiation reaction.

Electrodynamics and relativity: The special theory of relativity, Einstein's postulates, The geometry of relativity, The Lorentz transformations, The structure of space time. Proper time and proper velocity, relativistic energy and momentum, relativistic kinematics, relativistic dynamics.
Magnetism as a relativistic phenomena, How the fields transform, The field tensor, Electrodynamics in tensor notation, relativistic potentials.

Reference books:

1. Introduction to Electrodynamics by David J. Griffiths
2. Classical Electrodynamics by J. D. Jackson

Analog electronics: Concept of voltage source, concept of current source, Source equivalence, Four terminal network, Impedance matching, Superposition Theorem, Reciprocity Theorem, Thevenin's theorem, Norton's Theorem, The maximum power transfer theorem

Low frequency and high frequency and Power amplifiers using transistors - Sine wave generators - Wien bridge and phase shift oscillators - Multivibrator circuits - Triangle and square wave generation

Ideal operational amplifier: characteristics. Feedback types, Applications: voltage follower, Basic scaling circuits - current to voltage and voltage to current conversion – summing and difference amplifiers - Integrating and differentiating circuits

Digital Electronics

Number systems; decimal, binary, octal and hexadecimal system arithmetics; logic families; logic gates; Boolean algebra; De Morgan's laws; Half adder, Full adder, Comparators, Decoders, Multiplexers, Demultiplexers - Design of combinational circuits, Sequential circuits, flip flops; S-R flip flop, Clocked R-S flip flop, J-K flip flop, D-type flip flop, T flip flop, counters, Registers, A/D and *D/A* conversion characteristics.

References Books

1.J. Milman and C.C. Halkias, Electronic Devices and Circuits, McGraw-Hili (1981).
2.AP. Malvino, Electronics: Principles and Applications, Tata McGraw-Hili (1991).
3.A P. Malvino Donald P. Leach, Digital Principies and Applications - s" edition, McGraw-Hili 1994
4.Solis State Devices & Electronics, E; G Streetman & S K Banarje Prentice Hall

PH 6115: Atomic and Molecular Physics **L-T-P : 3-0-0**

Pauli exclusion principle: spectral terms from two equivalent electrons, calculation of Zeeman pattern, Paschen-Back effect, Stark effect in hydrogen, hyperfine structure and determination of nuclear spin and nuclear g factors, radiative transition probabilities, line width: Doppler broadening, natural broadening, collision broadening and Stark broadening.

Rotation, vibration and rotation-vibration spectra of diatomic molecules, selection rules, determination of rotational constants. Electronic spectra: Born-Oppenheimer approximation, (i) vibrational structure of electronic transition, progressions and sequences of vibrational bands, Intensity distribution, Franck-Condon principle, (ii) rotational structure of electronic transition, band head formation.

Raman spectra: Quantum and classical theory of Raman effect, Vibrational Raman spectrum, selection rules, Stokes and anti-Stokes lines, Rotational Raman spectrum, selection rule.

Books Recommended

1. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules, Longman (1996).
2. H. E. White, Introduction to Atomic Spectra, Tata McGraw Hill (1934).
3. G. Herzberg, Spectra of Diatomic Molecules (Vol. 1).
4. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, Tata McGraw Hill (1994).

PH 6116 Physics Lab –III **L-T-P : 3-0-6**

1. To study the Hysteresis Loop of a ferromagnetic material and calculate the energy loss
2. Determination of wavelength of an electron and verification of de-Broglie wave equation
3. Measuring the resistance of a noble metal as a function of temperature at various points
4. To determine the specific charge of an electron (the ration of charge to mass of electron)
5. To experimentally demonstrate the concept of quantization of energy levels according to Bohr's atomic model

Students will be able to:

At the end of this laboratory course, the students will be trained to operate experimental kits, collect and analyze the data to learn the Physics concepts behind these experiments.

PH 6117: Seminar **L-T-P : 0-0-2**

PH-6118: Physics of Semiconductor **L-T-P : 3-0-0**

Semiconductor in equilibrium: Equilibrium distribution of holes and electrons, Intrinsic carrier concentration and intrinsic Fermi level, Dopants and energy level, Extrinsic semiconductor and equilibrium distribution of electrons and holes, Compensation and charge neutrality.

Carrier transport Phenomena: Carrier drift and carrier diffusion, graded impurity distribution and Hall Effect.

Excess carrier in semiconductor: Optical absorption, Luminescence, Carrier life time and photoconductivity, Direct recombination of electron and holes, indirect recombination, traping quasi-Fermi level. Diffusion and drift of carriers, built in fields, diffusion and recombination. The continuity equation, Steady state carrier injection, the Haynes-Shockley experiment, gradients in quasi- Fermi level.

Junctions: The pn junction: pn junction under zero, forward and reverse bias, Built in potential and depletion layer width, junction capacitance, linearly graded junction.

Pn junction current, charge flow in pn junction, minority carrier concentration at depletion layer edge, minority carrier distribution, Ideal pn junction current,

Metal-semiconductor junctions: Schottky barriers, Rectifying contacts, Ohmic contact, typical schottky barriers, heterojunctions.

References:

1. Physics of Semiconductor devices, S M Sze

2. Semiconductor Physics and Devices, Donald A Neamen

3. Solid State Electronics Devices, B G Streetman, S Banerjee

PH 6119: Experimental Techniques L-T-P : 3-0-0

General experimental techniques, data collection, data processing, analog to digital conversion of data, signal to noise ratio, types of noise, noise reduction techniques.

Error analysis, significant figures, statistical methods, Linear and non-linear curve fitting, Chi-square test, use of graphs, interpretation of data from graphs, computational methods.

Vacuum, vacuum ranges, general vacuum techniques, pumps, rotary pump, diffusion pump, turbo molecular pump. Vacuum gauges, pirani, penning & McLeod gauges, seals, connectors & grease.

Detectors: optical detectors, photoemission detectors, Particle detectors and radioactive Decay: Interactions of charged particles and photons with matter; gaseous ionization detectors, scintillation counter, solid state detectors

Analytical techniques: X-ray diffractometer, spectrophotometers, scanning electron microscope, atomic force microscope, interferometers.

Books Recommended

1. Modern electronic instrumentation and measurement techniques, A. D. Helfrick and W. D. Cooper, Prentice Hall of India (1996).
2. Principles of measurement systems, J. P. Bentley, Longman (2000).
3. Introduction to Error Analysis (2^{nd} Ed), J. R. Taylor, University Science Books (1997).
4. Building Scientific apparatus, by J. H. Moore, Christopher C. Davis and Michael A. Coplan, Cambridge University Press; 4^{th} edition (2009).
5. A. Roth, Vacuum technology, Elsevier (1990).
6. Radiation detection and Measurements, G. Knoll, 3rd Edition
7. D. A. Skoog, F. J. Holler and T. A. Nieman, Principles of instrumental analysis, Saunders Coll. Publ. (1998).

PH 6120: Nuclear and Particle Physics **L-T-P : 3-0-0**

Nuclear properties: radius, size, mass, spin, moments, abundance of nuclei, binding energy, semi-empirical mass formula, excited states; Nuclear forces: deuteron, n-n and p-p interaction, nature of nuclear force, Yukawa hypothesis; Nuclear Models: liquid drop, shell and collective models; Nuclear decay and radioactivity: radioactive decay, detection of nuclear radiation, alpha, beta and gamma decays, radioactive dating;

Particle accelerators and detectors: cyclotron, synchrotron, ionization chamber, scintillation detectors, semiconductor detectors;

Elementary particles: Fundamental forces, properties mesons and baryons, symmetries and conservation laws, quark model, concept of colour charge, discrete symmetries, properties of quarks and leptons, particle interactions and Feynman diagrams.

Reference:

1. K. S. Krane, Introductory Nuclear Physics, John Wiley (1988).
2. R. R. Roy and B. P. Nigam, Nuclear Physics: Theory and Experiment, New Age (1967).
3. A. Das and T. Ferbel, Introduction to nuclear and particle physics, John Wiley (1994).
5. F. Halzen and A. D. Martin, Quarks and Leptons, John Wiley (1984).
6. Introduction to Particle Physics, David Griffiths

PH 6199 Project