MANONMANIAM SUNDARANAR UNIVERISTY,
TIRUNELVELI-12

# SYLLABUS

**PG - COURSES – AFFILIATED COLLEGES**

Course Structure for M. Sc. Physics
(Choice Based Credit System)
(with effect from the academic year 2023-2024 onwards )

| Semester-IV | | | | |
|---|---|---|---|---|
| **Part** | **Subject Status** | **Subject Title** | **Subject Code** | **Credit** |
| 3 | Core | NUCLEAR AND PARTICLE PHYSICS | | 5 |
| 3 | Core Practical- IV | ADVANCED PHYSICS EXPERIMENTS - II AND NUMERICAL METHODS IN C++ | | 4 |
| 3 | Core | PROJECT WITH VIVA VOCE | | 8 |
| 3 | Elective | ELECTRO MAGNETIC THEORY/ QUANTUM FIELD THEORY/ ADVANCED MATHEMATICAL PHYSICS | | 3 |
| 3 | SEC - 3 | SOLAR ENERGY UTILIZATION | | 2 |
| 3 | Extension Activity | CHOOSE ANY ONE FROM LIST - I | | 1 |

**Total Marks: 100    Internal Exam: 25 marks + External Exam: 75 marks**

A. **Scheme for internal Assessment**:
Maximum marks for written test: **15 marks**
**3 internal tests**, each of **I hour** duration shall be conducted every semester.
To the average of the **best two** written examinations must be added the marks scored in. The **assignment** for 5 marks and Seminar for 5 marks

The break up for internal assessment shall be:
Written test- 15 marks; Assignment -5 marks; Seminar-5 Marks  Total - 25 marks

**B. Scheme of External Examination**
**3 hrs.** examination at the end of the semester
A – Part :  1 mark question two - from each unit
B – Part :  5 marks question one - from each unit
C – Part :  8 marks question one - from each unit

- **Conversion of Marks into Grade Points and Letter Grades**

| S.No. | Percentage of Marks | Letter Grade | Grade Point | Performance |
|---|---|---|---|---|
| 1 | 90 - 100 | O+ | 10 | Outstanding |
| 2 | 80 - 89 | O | 9 | Excellent |
| 3 | 70 - 79 | A+ | 8 | Very Good |
| 4 | 60 - 69 | A | 7 | Good |
| 5 | 55 - 59 | B+ | 6 | Above Average |
| 6 | 50 - 54 | B | 5 | Pass |
| 7 | 0 - 49 | RA | - | ReAppear |
| 8 | Absent | AA | - | Absent |

- **Cumulative Grade Point Average (CGPA)**

$$\mathbf{CGPA} = \frac{\mathbf{\Sigma\,(GP \times C)}}{\mathbf{\Sigma C}}$$

- **GP** = Grade point, **C** = Credit
- CGPA is calculated only for Part-III courses
- CGPA for a semester is awarded on cumulative basis

- **Classification**

a) First Class with Distinction : CGPA $\geq$ 7.5*****
b) First Class : CGPA $\geq$ 6.0
c) Second Class : CGPA $\geq$ 5.0 and $<$ 6.0
d) Third Class : CGPA $<$ 5.0

# NUCLEAR AND PARTICLE PHYSICS

**Learning Objectives**

- Introduces students to the different models of the nucleus in a chronological order
- Imparts an in-depth knowledge on the nuclear force, experiments to study it and the types of nuclear reactions and their principles
- Provides students with details of nuclear decay with relevant theories
- Exposes students to the Standard Model of Elementary Particles and Higgs boson

**UNIT I: NUCLEAR MODELS**

Liquid drop model – Weizacker mass formula – Isobaric mass parabola –Mirror Pair - Bohr Wheeler theory of fission – shell model – spin-orbit coupling – magic numbers – angular momenta and parity of ground states – magnetic moment – Schmidt model – electric Quadrupole moment - Bohr and Mottelson collective model – rotational and vibrational bands.

**UNIT II: NUCLEAR FORCES**

Nucleon – nucleon interaction – Tensor forces – properties of nuclear forces – ground state of deuteron – Exchange Forces - Meson theory of nuclear forces – Yukawa potential – nucleon- nucleon scattering – effective range theory – spin dependence of nuclear forces - charge independence and charge symmetry – isospin formalism.

**UNIT III: NUCLEAR REACTIONS**

Kinds of nuclear reactions – Reaction kinematics – Q-value – Partial wave analysis of scattering and reaction cross section – scattering length – Compound nuclear reactions – Reciprocity theorem – Resonances – Breit Wigner one level formula – Direct reactions - Nuclear Chain reaction – four factor formula.

**UNIT IV: NUCLEAR DECAY**

Beta decay – Continuous Beta spectrum – Fermi theory of beta decay - Comparative Half-life – Fermi Kurie Plot – mass of neutrino – allowed and forbidden decay –– neutrino physics – Helicity - Parity violation - Gamma decay – multipole radiations – Angular Correlation - internal conversion – nuclear isomerism – angular momentum and parity selection rules.

**UNIT V: ELEMENTARY PARTICLES**

Classification of Elementary Particles – Types of Interaction and conservation laws – Families of elementary particles – Isospin – Quantum Numbers – Strangeness –

Hypercharge and Quarks –SU (2) and SU (3) groups-Gell Mann matrices– Gell Mann Okuba Mass formula- Quark Model. Standard model of particle physics – Higgs boson.

**TEXT BOOKS**

1. D. C. Tayal – Nuclear Physics – Himalaya Publishing House (2011).
2. K. S. Krane – Introductory Nuclear Physics – John Wiley & Sons (2008).
3. R. Roy and P. Nigam – Nuclear Physics – New Age Publishers (1996).
4. S. B. Patel – Nuclear Physics – An introduction – New Age International Pvt Ltd Publishers (2011).
5. S. Glasstone – Source Book of Atomic Energy – Van Nostrand Reinhold Inc.,U.S. 3rd Revised edition (1968).

**REFERENCE BOOKS**

1. L.J. Tassie – The Physics of elementary particles – Prentice Hall Press (1973).
2. H.A. Enge – Introduction to Nuclear Physics – Addison Wesley, Publishing Company. Inc. Reading. New York, (1974).
3. Kaplan – Nuclear Physics – 1989 – 2nd Ed. – Narosa (2002).
4. Bernard L Cohen – Concepts of Nuclear Physics – McGraw Hill Education (India) Private Limited; 1 edition (2001).
5. B.L. Cohen, 1971, Concepts of Nuclear Physics, TMCH, New Delhi.

**WEB SOURCES**

1. http://bubl.ac.uk/link/n/nuclearphysics.html
2. http://www.phys.unsw.edu.au/PHYS3050/pdf/Nuclear_Models.pdf
3. http://www.scholarpedia.org/article/Nuclear_Forces
4. https://www.nuclear-power.net/nuclear-power/nuclear-reactions/
5. http://labman.phys.utk.edu/phys222core/modules/m12/nuclear_models.html
6. https://www.ndeed.org/EducationResources/HighSchool/Radiography/radioactivedec ay.html

## Practical – IV: ADVANCED PHYSICS EXPERIMENTS – II AND NUMERICAL METHODS IN C++

**Learning Objectives**

- To apply theoretical knowledge through hands-on experiments in order to analyze and understand the characteristics and behaviors of various physical and electronic systems, while developing practical skills in measurement, data analysis, and circuit design.
- To familiarize the students with numerical methods used in problem-solving by writing programs using the high level language C++

**Advanced Physics Experiments – II and Numerical Methods in C++**

**Section A: Advanced Physics Experiments – II** (Any 6 Experiments)

1. Investigate the equilibrium points of the logistic map equation Xn+1 = aXn (1-Xn) for various parameter values and initial conditions:
   a) Determine the equilibrium points for ‘a’ ranging from 0.5 to 2.5 with a step size of 0.1 considering x0=0.1.
   b) Explore the behavior of the logistic map for ‘a’ values between 3.5 and 4.0 with a step size of 0.05 for x0=0.2.
   c) Analyze the dynamics near the period-doubling bifurcation point at a≈3.828, considering x0=0.3.
   d) Plot xn versus n for each scenario and generate bifurcation diagrams to visualize the system's behavior.
2. Determination of resistivity of a semiconductor by Four Probe Method.
3. Examine the input-output characteristics of an ADC or DAC IC (0800 series). The characteristics may include parameters such as linearity, accuracy, resolution and dynamic range.
4. Photo Conductivity Experiment:
   a) To plot the current-voltage characteristics of a CdS Photo Resistor (LDR) at constant irradiance.
   b) To measure the Photo current as a function of irradiance at constant voltage
5. Determination of the distance between two tracks of a CD and a DVD using a Solid state laser
6. Verification of Thevenin’s and Max power theorems
7. Study the Characteristics of a Load cell
8. Design of a Serial Shift Registers using necessary Flip-Flop ICs
9. Design of Encoder and Decoder Circuits using necessary ICs
10. Study of a quartz crystal (1 MHz) and construction of a Pierce crystal Oscillator using digital inverters
11. UV spectral data analysis for the given spectrum
12. Simulation of satellite orbit around the earth using the universal law of gravitation in Scilab

**Section – B : Numerical Methods in C++** (Any SIX programs with Algorithm and Flow chart)

1. Algebraic and Transcendental equation.
   a) Solution of the given equations using Newton Raphson Method – manual calculation.
   b) C++ program to find the solution using N-R method and verification.
2. Algebraic and Transcendental equations.
   a) Solution of the given equations using Bisection Method – manual

calculation.

b) C++ program to find the solution using Bisection method and verification.

3. Curve Fitting – Linear Fit
   a) Principle of least square and fitting a straight line.
   b) C++ program to fit a straight line using the given data related with any physics experiment.
4. Curve Fitting – Non Linear Fit
   a) Principle of fitting a second degree polynomial using method of least square
   b) C++ program to fit a polynomial using the given data related with any physics experiment.
5. Interpolation
   a) Derive Lagrangian interpolation formula.
   b) C++ program to interpolate using the given data related with any physics experiment by Lagrangian Method.
6. Solution of simultaneous equations -Gauss Elimination method.
   a) Procedure to solve Simultaneous equations using Gauss Elimination (GE) Method
   b) C++ program for solving unknown branch currents in Wheatstone's bridge using GE method.
7. Numerical solution of ordinary Differential Equations.
   a) Derivation of Exponential law of Radioactive decay.
   b) RK 4th order method of solving a given 1st order differential equation.
   c) C++ program using RK method to solve radioactive problem – Compare output with the analytical result.
8. Area under the Curve - Numerical integration
   a) Derivation of Trapezoidal and Simpson's rule
   b) C++ programs for Trapezoidal and Simpson 1/3 rule
   c) Comparison of the program output with direct integration.
9. Random Number Generation and Montecarlo Method
   a) Generate and scale the random numbers for the desired range using the C++ library functions.
   b) Evaluate the given integral using Montecarlo method.
10. Matrix Multiplication
    a) Multiplication of two given matrices
    b) Rotation matrix definition.
    c) C++ program to rotate the given 2D- object about the origin using rotation matrix through the given angle.
11. Inverse of a Matrix

a) Procedure to determine the Inverse of a Matrix using Gauss elimination Method.
b) C++ Program to find the Inverse of a Matrix using Gauss Elimination Method.

12. Numerical Differentiation
    a) Numerical differentiation – related to any physical problem
    b) Derivation of Newton's law of cooling –equation
    c) C++ program to verify the Newton's law of cooling from the given experimental data.

# SOLAR ENERGY UTILIZATION

**Learning Objectives**

- To impart fundamental aspects of solar energy utilization.
- To give adequate exposure to solar energy related industries
- To harness entrepreneurship skills
- To understand the different types of solar cells and channelizing them to the different sectors of society
- To develop an industrialist mindset by utilizing renewable source of energy

**UNIT I**

**HEAT TRANSFER & RADIATION ANALYSIS**

Introduction to sun and solar energy – Conduction, Convection and Radiation – Solar Radiation at the earth's surface – Earth radiation budget- Determination of solar time – Solar energy measuring methods and instruments- Analysis of Solar insolation .

**UNIT II**

**SOLAR COLLECTORS**

Physical principles of conversion of solar radiation into heat flat plate collectors - General characteristics – Focusing collector systems – Thermal performance evaluation of optical loss.

**UNIT III**

**SOLAR HEATERS**

Types of solar water heater - Solar heating system – Collectors and storage tanks – Solar ponds – Solar cooling systems – Design and cost estimation of a solar thermal system (Load analysis, system design, component list, price break down)

**UNIT IV**

**SOLAR ENERGY CONVERSION**

Photo Voltaic principles – Types of solar cells – Crystalline silicon/amorphous silicon and Thermo - electric conversion - process flow of silicon solar cells- different approaches on the process- texturization, diffusion, Antireflective coatings, metallization-Emerging solar cell technologies.

**UNIT V**

**NANOMATERIALS IN FUEL CELL APPLICATIONS**

Use of nanostructures and nanomaterial in fuel cell technology - high and low temperature fuel cells, cathode and anode reactions, fuel cell catalysts, electrolytes, ceramic catalysts. Use of Nano technology in hydrogen production and storage.
Industrial visit – data collection and analysis - presentation

**TEXT BOOKS**

1. Solar energy utilization -G.D. Rai –Khanna publishers – Delhi 1987.
2. Carbon Nano forms and Applications", Maheshwar Sharon, Madhuri Sharon, Mc Graw-Hill, 2010.
3. Solar Energy Engineering: Processes and Systems‟, Soteris A. Kalogirou Academic Press, London, 2009
4. Solar Energy – Fundamentals Design, Modelling and applications, Tiwari Narosa Publishing House, New Delhi, 2002
5. Solar Energy, Sukhatme S.P. Tata McGraw Hill Publishing Company Ltd., New Delhi, 1997.

**REFERENCE BOOKS**

1. Energy – An Introduction to Physics – R.H.Romer, W.H.Freeman.(1976)
2. Solar energy thermal processes – John A.Drife and William. (1974)
3. John W. Twidell& Anthony D.Weir, 'Renewable Energy Resources,2005
4. John A. Duffie, William A. Beckman, Solar Energy: Thermal Processes, 4th Edition, john Wiley and Sons, 2013
5. Duffie, J.A., Beckman, W.A. , "Solar Energy Thermal Process", John Wiley and Sons,2007.
6. Solar Domestic Water Heating "The Earthscan Expert Handbook for Planning, Design and Installation" published by Earthscan Ltd. ISBN: 978-1-84407-736-6
7. Solar Water and Pool Heating Manual: Design and Installation & Repair and Maintenance, FSEC-IN-24.

Free download at: [PDF] Solar Water and Pool Heating Manual File Format: PDF/Adobe Acrobat - Quick View Pool Heating Manual. Design and Installation. &. Repair and Maintenance. Florida Solar Energy Center. Cocoa, Florida

**WEB SOURCES**

1. https://pdfs.semanticscholar.org/63a5/a69421b69d2ce9f359bbfc86c63556f9a4fb
2. https://books.google.vg/books?id=lXHcwZo9XwC&sitesec=buy&source=gbs_vpt_read
3. www.nptel.ac.in/courses/112105051
4. www.freevideolectures.com
5. http://www.e-booksdirectory.com

# ELECTROMAGNETIC THEORY

## Learning Objectives

- To acquire knowledge about boundary conditions between two media and the technique of method of separation of variables
- To understand Biot – Savart's law and Ampere's circuital law
- To comprehend the physical ideas contained in Maxwell's equations, Coulomb & Lorentz gauges, conservation laws
- To assimilate the concepts of propagation, polarization, reflection and refraction of electromagnetic waves
- To grasp the concept of plasma as the fourth state of matter

## UNIT I: ELECTROSTATICS

Boundary value problems and Laplace equation – Boundary conditions and uniqueness theorem – Laplace equation in three dimension – Solution in Cartesian and spherical polar coordinates – Examples of solutions for boundary value problems. Polarization and displacement vectors - Boundary conditions - Dielectric sphere in a uniform field – Molecular polarizability and electrical susceptibility – Electrostatic energy in the presence of dielectric – Multipole expansion.

### UNIT II: MAGNETO STATICS

Biot-Savart's Law - Ampere's law - Magnetic vector potential and magnetic field of a localized current distribution - Magnetic moment, force and torque on a current distribution in an external field - Magneto static energy - Magnetic induction and magnetic field in macroscopic media - Boundary conditions - Uniformly magnetized sphere.

## UNIT III: MAXWELL EQUATIONS

Faraday's laws of Induction - Maxwell's displacement current - Maxwell's equations - Vector and scalar potentials - Gauge invariance - Wave equation and plane wave solution- Coulomb and Lorentz gauges - Energy and momentum of the field - Poynting's theorem - Lorentz force - Conservation laws for a system of charges and electromagnetic fields.

## UNIT IV: WAVE PROPAGATION

Plane waves in non-conducting media - Linear and circular polarization, reflection and refraction at a plane interface - Waves in a conducting medium - Propagation of waves in a rectangular wave guide. Inhomogeneous wave equation and retarded potentials - Radiation from a localized source - Oscillating electric dipole

### UNIT V: ELEMENTARY PLASMA PHYSICS

The Boltzmann Equation - Simplified magneto-hydrodynamic equations - Electron plasma oscillations - The Debye shielding problem - Plasma confinement in a magnetic field - Magneto- hydrodynamic waves - Alfven waves and magneto sonic waves.

**TEXT BOOKS**

1. D.J.Griffiths , 2002, Introductionto Electrodynamics, 3rd Edition, Prentice-Hall of India, New Delhi.
2. J.R. Reitz, F. J. Milford and R. W. Christy, 1986, Foundations of Electromagnetic Theory, 3rd edition, Narosa Publishing House, New Delhi.
3. J.D. Jackson, 1975, Classical Electrodynamics, Wiley Eastern Ltd. New Delhi.
4. J.A. Bittencourt, 1988, Fundamentals of Plasma Physics, Pergamon Press, Oxford.
5. Gupta, Kumar and Singh, Electrodynamics, S. Chand & Co., New Delhi

**REFERENCE BOOKS**

1. W.Panofsky and M. Phillips, 1962, Classical Electricity and Magnetism, Addison Wesley, London.
2. J.D. Kraus and D. A. Fleisch, 1999, Electromagnetics with Applications, 5th Edition, WCB McGraw-Hill, New York.
3. B.Chakraborty, 2002, Principles of Electrodynamics, Books and Allied, Kolkata.
4. P.Feynman, R. B. Leighton and M. Sands, 1998, The Feynman Lectures on Physics, Vols. 2, Narosa Publishing House, New Delhi.
5. Andrew Zangwill, 2013, Modern Electrodynamics, Cambridge University Press, USA

**WEB SOURCES**

1. http://www.plasma.uu.se/CED/Book/index.html
2. http://www.thphys.nuim.ie/Notes/electromag/frame-notes.html
3. http://www.thphys.nuim.ie/Notes/em-topics/em-topics.html
4. http://dmoz.org/Science/Physics/Electromagnetism/Courses_and_Tutorials/
5. https://www.cliffsnotes.com/study-guides/physics/electricity-andmagnetism/electrostatics

# QUANTUM FIELD THEORY

## Learning Objectives

- To school the students about the analytical and numerical techniques of nonlinear dynamics.
- To make the students understand the concepts of various coherent structures.
- To train the students on bifurcations and onset of chaos.
- To educate the students about the theory of chaos and its characterization.
- To make the students aware of the applications of solitons, chaos and fractals.

**UNIT I**

**SYMMETRY PRINCIPLES**

Relativistic kinematics, relativistic waves, Klein-Gordon (KG) equation as a relativistic wave equation, treatment of the KG equation as a classical wave equation: its Lagrangian and Hamiltonian, Noether's theorem and derivation of energy-momentum and angular momentum tensors as consequence of Poincaré symmetry, internal symmetry and the associated conserved current.

**UNIT II**
**QUANTIZATION OF KLEIN-GORDAN FIELD**
Canonical quantization of the KG field, solution of KG theory in Schrödinger and Heisenberg pictures, expansion in terms of creation and annihilation operators, definition of the vacuum and N-particle eigenstates of the Hamiltonian, vacuum expectation values, propagators, spin and statistics of the KG quantum.

**UNIT III**
**QUANTIZATION OF DIRAC FIELD**
Review of Dirac equation and its quantization, use of anti commutators, creation and destruction operators of particles and antiparticles, Dirac propagator, energy, momentum and angular momentum, spin and statistics of Dirac quanta.

**UNIT IV**
**QUANTIZATION OF ELECTROMAGNETIC FIELDS**
Review of free Maxwell's equations, Lagrangian, gauge transformation and gauge fixing, Hamiltonian, quantization in terms of transverse delta functions, expansion in terms of creation operators, spin, statistics and propagator of the photon.

**UNIT V**
**PERTURBATIVE INTERACTION AT TREE LEVEL**
Introduction to interacting quantum fields, Wick's Theorem, Feynman Diagram, Examples from quantum electrodynamics at the tree level: positron-electron and electron-electron scattering.

**TEXT BOOKS**

1. J.D. BjorkenandS. D. Drell,Relativistic Quantum FieldsDavid
2. An Introduction to Quantum Field Theory by M. Peskin and D. V. Schroeder
3. Quantum Field theory: From Operators to Path Integrals, 2nd edition by Kerson Huang
4. Quantum Field Theory by Mark Srednicki
5. Quantum Field Theory by Claude Itzykson and Jean Bernard Zuber.

**REFERENCE BOOKS**

1. V.B. Berestetskii,E.M.LifshitzandL.P.Pitaevskii,QuantumElectrodynamics
2. Introduction to the Theory of Quantized Fields by N. N. Bogoliubov and D. V. Shirkov (1959)
3. Quantum Field Theory by L. H. Ryder (1984)
4. Quantum Field Theory by L. S. Brown (1992)
5. Quantum Field Theory: A Modern Introduction by M. Kaku (1993)

**WEB SOURCES**

1. https://homepages.dias.ie/ydri/QFTNOTES4v2.pdf
2. https://www.scirp.org/(S(i43dyn45teexjx455qlt3d2q))/reference/referencespapers.aspx?referenceid=2605249
3. https://archive.nptel.ac.in/courses/115/106/115106065/
4. http://www.nhn.ou.edu/~milton/p6433/p6433.html
5. https://plato.stanford.edu/entries/quantum-field-theory/

# ADVANCED MATHEMATICAL PHYSICS

**Learning Objectives**

- To educate and involve students in the higher level of mathematics and mathematical methods relevant and applicable to Physics.

**UNIT I**

**DISCRETE GROUPS**

Definition of a group, subgroup, class, Lagrange's theorem, invariant subgroup, Homomorphism and isomorphism between two groups.

Representation of a group, unitary representations, reducible and irreducible representations Schur's lemmas, orthogonality theorem, character table, reduction of Kronecker product of representations, criterion for irreducibility of a representation.

**UNIT II**

**CONTINUOUS GROUPS**

Infinitesimal generators, Lie algebra; Rotation group, representations of the Lie algebra of the rotation group, representation of the rotation group, D- matrices and their basic properties. Addition of two angular momenta and C.G. coefficients, Wigner-Eckart theorem.

**UNIT III**

**SPECIAL UNITARY GROUPS**

Definition of unitary, unimodular groups SU(2) and SU(3). Lie algebra of SU(2). Relation between SU(2) and rotation group. Lie algebra of SU(3) Gellmann's matrices. Cartan form of the SU(3). Lie algebra, roots and root diagram for SU(3). Weights and their properties, weight diagrams for the irreducible representations 3.3*-, 6,6 8, 10 and 10 of SU(3). Direct product of two SU(3) representations, Young tableaux method of decomposition of products of IR's illustrations with the representations of dim<10. C.G.coefficients for 3 x 3* and 3 x 6 representations. SU(3) symmetry in elementary particle physics, quantum numbers of hadrons and SU(2) and SU(3) classification of hadrons.

**UNIT IV**

**TENSORS**

Cartesian vectors and tensors illustration with moment of inertia, conductivity, dielectric tensors. Four vector in special relativity, vectors and tensors under Lorentz transformations, Illustration from physics. Vectors and tensors under general co-ordinate transformations, contravariant and covariant vectors and tensors, mixed tensors; tensor algebra, addition, subtraction, direct product of tensors, quotient theorem, symmetric and antisymmetric tensors.

**UNIT V**

**TENSOR CALCULUS**

Parallel transport, covariant derivative, affine connection. Metric tensor. Expression for Christoffel symbols in terms of and its derivatives (assuming D g = 0. Curvature tensor, Ricci tensor and Einstein tensor. Bianchi identities, Schwarzschild solution to the Einstein equation G=0.

**TEXT BOOKS**

1. A.W.Joshi, Group Theory for Physicists
2. D.B.Lichtenberg, Unitary Symmetry and Elementary Particles
3. E.Butkov, Mathematical Physics
4. J.V.Narlikar, General Relativity & Cosmology
5. R. Geroch, Mathematical Physics, The University of Chicago press (1985).

**REFERENCE BOOKS**

1. M.Hamermesh Group Theory
2. M.E.Rose: Elementary Theory of Angular Momentum
3. Georgi : Lie Groups for Physicists
4. E.A.Lord: Tensors, Relativity & Cosmology
5. P. Szekeres, A course in modern mathematical physics: Groups, Hilbert spaces and differential geometry, Cambridge University Press.

**WEB SOURCES**

1. https://vdoc.pub/documents/unitary-symmetry-and-elementary-particlesc4qsfejthkc0
2. https://physics.iith.ac.in/HEP_Physics/slides/poplawskitalk.pdf
3. https://www.hindawi.com/journals/amp/
4. https://projecteuclid.org/journals/advances-in-theoretical-andmathematical-physics
5. https://www.springer.com/journal/11232