Course Code: GE 11

Course Title: ELECTRICITY AND MAGNETISM

Total Credits: 04 (Credits: **Theory: 03, Practical: 01**)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course begins with theorems of network analysis which are required to perform the associated experiments in the laboratory. Then course delves into the elementary vector analysis, an essential mathematical tool for understanding static electric field and magnetic field. By the end of the course student should appreciate Maxwell's equations.

Course Learning Outcomes (Theory): At the end of this course the student will be able to,
- Apply Coulomb's law to line, surface, and volume distributions of charges.
- Apply Gauss's law of electrostatics to distribution of charges
- Understand the effects of electric polarization and concepts of bound charges in dielectric materials
- Understand and calculate the vector potential and magnetic field of arbitrary current distribution
- Understand the concept of bound currents and ferromagnetism in magnetic materials

THEORY (Credit: 03; 45 Hours)

Unit 1:   **Hours: 15**
Network Analysis: Superposition, Thevenin, Norton theorems and their applications in DC and AC circuits with more than one sources. Maximum Power Transfer theorem for AC circuits

(6 Hours)

Mathematical Preliminaries:

Concept of scalar and vector fields, Gradient of a scalar field, Divergence and curl of vector fields and their physical interpretation, Conservative forces and Laplace and Poisson equations.

(4 Hours)

Concept of a line integral of a scalar and vector field, surface integral of vector fields and volume integral. Gauss's theorem, Stoke's theorem.

(5 Hours)

Unit 2:   Hours: 15

Electric Field and Electric Potential for continuous charge distributions: Electric field due to a line charge, surface charge and volume charge distributions, Electric field vector as negative gradient of scalar potential, Ambiguities of Electric potential, Differential and integral forms of Gauss's Law, Applications of Gauss's Law to various charge distributions with spherical, cylindrical and planar symmetries. Uniqueness theorem.

(7 Hours)

Electric Field in Matter: Bound charges due to polarization and their physical interpretation. Average electric field inside a dielectric, Electric Field in spherical and cylindrical cavities of a dielectric, Displacement vector and its boundary conditions, Gauss' Law in the presence of dielectrics, Linear dielectrics: electric susceptibility and dielectric constant, Boundary value problems with linear dielectrics.

(8 Hours)

Unit 3:   Hours: 15

Magnetic Field: Divergence and curl of magnetic field B, Magnetic field due to arbitrary current distribution using Biot-Savart law, Ampere's law, integral and differential forms of Ampere's Law, Vector potential and its ambiguities.

(4 Hours)

Magnetic Properties of Matter: Magnetization vector. Bound Currents, Magnetic Intensity. Differential and integral form of Ampere's Law in the presence of magnetised materials. Magnetic susceptibility and permeability. Ferromagnetism (Hund's rule).

(6 hours)

Electrodynamics: Faraday's Law, Lenz's Law, inductance. Electromotive force, Ohm's Law ($\vec{J} = \sigma \vec{E}$). Energy stored in a Magnetic Field. Charge Conservation, Continuity equation, Differential and integral forms of Maxwell's equations in matter.

(5 hours)

References:
Essential Readings:
1) Introduction to Electrodynamics, D. J. Griffiths, 4th Edn., 2015, Pearson Education India Learning Private Limited.
2) Schaum's Outlines of Electromagnetics, M. Nahvi and J. A. Edminister, 2019, McGraw-Hill Education.
3) Electromagnetic Fields and Waves, Paul Lorrain and Dale Corson, 1991, W. H. Freeman.
4) Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
5) Network, Lines and Fields, John D. Ryder, 2nd Edn., 2015, Pearson.
6) Introductory circuit analysis, R. Boylestead, 2016, Pearson.
7) Electricity and Magnetism, Tom Weideman, University of California Davis.
   [url: https://zhu.physics.ucdavis.edu/Physics9C-C_2021/Physics%209C_EM%20by%20Tom%20Weideman.pdf]

Additional Readings:
1) Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education
2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
3) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley

PRACTICAL (Credit: 01; 30 Hours)

Course Learning Outcome (Practical):
- To understand working of Arduino Microcontroller System
- To use Arduino to measure time, count events and time between events
- To use Arduino to measure voltage/current/resistance
- To use Arduino to measure various physical parameters like magnetic field

Unit I (Mandatory)
Arduino Programming
Introduction to Arduino Microcontroller platform. Getting acquainted with the Arduino IDE and Basic Sketch structure. Digital Input and output. Measuring time and events. Measuring analog voltage. Generating analog voltage using Pulse Width Modulation. Serial communication and serial monitor. Programming using Interrupts.

Unit II Exploring electrical properties of matter using Arduino (at least one experiment)
1) To study the characteristics of a series RC Circuit.
2) To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, Impedance at resonance, (c) Quality factor Q, and (d) Band width.
3) Diode Charateristics:
   a) To study characteristics of diode and estimate Boltzman constant.
   b) To study characteristics of LED and estimate Planck's constant

Unit III Exploring magnetic properties of matter using Arduino
To verify Faraday's law and Lenz's law by measuring induced voltage across a coil subjected to varying magnetic field. Also, estimate dipole moment of the magnet.

Unit IV DC and AC Bridges (at least one experiment)
1) To compare capacitances using De Sauty's Bridge
2) To determine a Low Resistance by Carey - Foster Bridge

Unit V Network Theorems (at least one experiment)
1) To verify the Thevenin and Norton theorems
2) To verify the Superposition, and Maximum Power Transfer Theorems

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) Engineering Practical Physics, S. Panigrahi and B.Mallick, 2015, Cengage Learning India Pvt. Ltd.
3) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th Ed.2011, Kitab Mahal
4) Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press

Course Code: GE 12
Course Title: **THERMAL PHYSICS**
Total Credits: 04 (Credits: Theory: 03, Practical: 01)
Total Hours: Theory: 45, Practical: 30

Course Objectives: This course will review the basic concepts of Thermodynamics, Kinetic Theory of gases with a brief introduction to Statistical Mechanics. The primary goal is to understand the applications of fundamental laws of thermodynamics to various systems and processes. This coursework will also enable the students to understand the connection between the macroscopic observations of physical systems and microscopic behavior of atoms and molecule through statistical mechanics.

Course Learning Outcomes: At the end of this course, students will,

- Get an essence of the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations. They are also expected to learn Maxwell's thermodynamic relations.
- Know the fundamentals of the kinetic theory of gases, Maxwell-Boltzman distribution law, mean free path of molecular collisions, viscosity, thermal conductivity and diffusion.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- Learn the basics of quantum statistical distributions, viz., the Bose-Einstein statistics and the Fermi-Dirac statistics.

In the laboratory course, the students are expected to: Measure of Planck's constant using black body radiation, determine Stefan's Constant, coefficient of thermal conductivity of a bad conductor and a good conductor, determine the temperature coefficient of resistance, study variation of thermo-emf across two junctions of a thermocouple with temperature etc.

THEORY (Credit: 03; 45 Hours)

Unit 1:   **Hours: 12**

Laws of Thermodynamics: Fundamental basics of Thermodynamic system and variables, Zeroth Law of Thermodynamics and temperature, First law and internal energy, various thermodynamical processes, Applications of First Law: general relation between C_P and C_V, work done during various processes, Compressibility and Expansion Coefficient, reversible

and irreversible processes, Second law: Kelvin-Planck and Clausius statements , Carnot engine, Carnot cycle and theorem, basic concept of Entropy, Entropy changes in reversible and irreversible processes, Clausius inequality, Entropy-temperature diagrams.

Unit 2: Hours: 8
Thermodynamical Potentials: Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell's relations and applications - Clausius Clapeyron Equation, Expression for (C_P − C_V), C_P/C_V, TdS equations, energy equations for ideal gases.

Unit 3: Hours: 8
Kinetic Theory of Gases: Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (zeroth order only), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case).

Unit 4: Hours: 7
Theory of Radiation: Blackbody radiation, Spectral distribution, Derivation of Planck's law, Deduction of Wien's law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.

Unit 5: Hours: 10
Statistical Mechanics: Macrostate and Microstate, phase space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann law, Fermi-Dirac distribution law - Bose-Einstein distribution law - comparison of three statistics.

PRACTICAL (Credit: 01; 30 Hours)

- Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the thermal physics lab, including necessary precautions.
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

Every student must perform at least four experiments from the following list.

1) To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2) Measurement of Planck's constant using black body radiation.
3) To determine Stefan's Constant.
4) To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
5) To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method by steam or electrical heating.
6) To determine the temperature co-efficient of resistance by Platinum resistance thermometer.

7) To study the variation of thermos-emf across two junctions of a thermocouple with temperature.

References (For Theory):
Essential Readings:
1) A Treatise on Heat, Meghnad Saha, and B.N. Srivastava, 1969, Indian Press.
2) Heat and Thermodynamics, M.W.Zemasky and R. Dittman, 1981, McGraw Hill.
3) Thermodynamics, Kinetic theory and statistical thermodynamics, F. W. Sears and G. L. Salinger. 1988, Narosa.
4) Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.
5) Thermal Physics: S.C.Garg, R. M.Bansal and C.K. Ghosh, 2nd Ed. Tata McGraw-Hill.

Additional Readings:
1) An Introduction to Thermal Physics: D. Schroeder 2021, Oxford Univ. Press (earlier published by Pearsons).
2) Concepts in Thermal Physics: Blundell and Blundell, 2nd Ed. 2009, Oxford Univ. Press.
3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company.

References (For Laboratory Work):
1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal.
3) A Laboratory Manual of Physics for Undergraduate Classes, D.P. Khandelwal, 1985, Vani Publication.
4) Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press.
5) An Advanced Course in Practical Physics: D. Chattopadhyay and P.C. Rakshit, New Central Book Agency

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Course Code: GE 13

Course Title: MODERN PHYSICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

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Course Objectives: The objective of this course is to teach the physics foundation necessary for learning various topics in modern physics which are crucial for understanding atoms, molecules, photons, nuclei and elementary particles. These concepts are also important to understand phenomena in Laser physics, condensed matter physics and astrophysics.

Course Learning Outcomes: After getting exposure to this course, the following topics would have learnt,

- Main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics, laying the foundation of modern physics.
- Formulation of Schrodinger equation and the idea of probability interpretation associated with wave-functions.
- The spontaneous and stimulated emission of radiation, optical pumping and population inversion. Basic lasing action.
- The properties of nuclei like density, size, binding energy, nuclear force and structure of atomic nucleus, liquid drop model and mass formula.
- Radioactive decays like alpha, beta, gamma decay. Neutrino, its properties and its role in theory of beta decay.
- Fission and fusion: Nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.

In the laboratory course, the students will get opportunity to measure Planck's constant, verify photoelectric effect, determine e/m of electron and work function of a metal. They will also find wavelength of Laser sources by single and double slit experiment, wavelength and angular spread of He-Ne Laser using plane diffraction grating.

THEORY (Credit: 03; 45 Hours)

Unit 1:   **Hours: 10**

Origin of Modern Physics Blackbody Radiation: Failure of explanation from classical theory; Planck's idea of a quantum; Quantum theory of Light: Photo-electric effect and Compton scattering. de Broglie wavelength and matter waves; Davisson-Germer experiment;

Wave description of particles by wave packets. Group and Phase velocities and relation between them.

Unit 2   Hours: 10
Problems with Rutherford model: Instability of atoms and observation of discrete atomic spectra; Bohr's quantization rule and atomic stability; calculation of energy levels for hydrogen-like atoms and their spectra.
Uncertainty principle: Gamma ray microscope thought experiment; Wave-particle duality leading to Heisenberg uncertainty principle; Impossibility of an electron being in the nucleus. Energy-time uncertainty principle; origin of natural width of emission lines.

Unit 3   Hours: 10
Basics of quantum Mechanics: Two-slit interference experiment with photons and electrons; Concept of wave functions, linearity and superposition. Time independent Schrodinger wave equation for non-relativistic particles; Momentum and Energy operators; physical interpretation of a wave function, probabilities, normalization and probability current densities in one dimension. Problem: One dimensional infinitely rigid box. An application: Quantum dot.

Unit 4   Hours: 5
X-rays: Ionizing Power, X-ray Diffraction, Bragg's Law. Critical Potentials, X-rays-Spectra: Continuous and Characteristic X-rays, Moseley's Law.
LASERs: Properties and applications of Lasers. Emission (spontaneous and stimulated emissions) and absorption processes, Metastable states, components of a laser and lasing action.

Unit 5   Hours: 10
Nuclear Physics: Size and structure of atomic nucleus and its relation with atomic weight; Nature of nuclear force, Stability of the nucleus; N-Z graph, Drip line nuclei, Binding Energy, Liquid Drop model: semi-empirical mass formula.
Radioactivity: Different equilibrium, Alpha decay; Beta decay: energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation:
Fission and fusion: Mass deficit and generation of energy; Fission: nature of fragments and emission of neutrons. Fusion and thermonuclear reactions driving stellar evolution (brief qualitative discussions only).

References:
Essential Readings:
1) Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.

2) Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.

3) Modern Physics for Scientists and Engineers by S T Thornton and A Rex, 4th edition, Cengage Learning, 2013.

4) Concepts of Nuclear Physics by B L Cohen, Tata McGraw Hill Publication, 1974.
5) Quantum Mechanics: Theory and Applications, (2019), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, New Delhi

Additional Readings:
1) Six Ideas that Shaped Physics: Particle Behave like Waves, T.A. Moore, 2003, McGraw Hill.
2) Thirty years that shook physics: the story of quantum theory, George Gamow, Garden City, NY: Doubleday, 1966.
3) New Physics, ed. Paul Davies, Cambridge University Press (1989).
4) Quantum Theory, David Bohm, Dover Publications, 1979.
5) Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
6) Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
7) Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.

PRACTICAL (Credit: 01; 30 Hours)

- Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the modern physics lab, including necessary precautions.
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors. Application to the specific experiments done in the lab.

Every student must perform at least 06 experiments from the following list of experiments.

1) Measurement of Planck's constant using black body radiation and photo-detector.
2) Photo-electric effect: estimate Planck's constant using graph of maximum energy of photo-electrons versus frequency of light.
3) To determine work function of material of filament of directly heated vacuum diode.
4) To determine the Planck's constant using LEDs, using at least 4 LEDs.
5) To determine the wavelength of H-alpha emission line of Hydrogen atom.
6) To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
7) To setup the Millikan oil drop apparatus and determine the charge of an electron.
8) To show the tunneling effect in tunnel diode using I-V characteristics.
9) To determine the wavelength of laser source using diffraction of single slit.
10) To determine wavelength and angular spread of He-Ne laser using plane diffraction grating.
11) To determine the wavelength of laser source using diffraction of double slits.

References (for Laboratory Work):

1) Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.

2) Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.

3) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.

4) Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press.

5) B. Sc. Practical Physics, Geeta Sanon, R. Chand, 2016.

Course Objectives: This course is meant to introduce undergraduate students to the wonders of the Universe. Students will understand how astronomers over millennia have come to understand mysteries of the universe using laws of geometry and physics, and more recently chemistry and biology. They will be introduced to the Indian contribution to astronomy starting from ancient times up to the modern era. They will learn about diverse set of astronomical phenomenon, from the daily and yearly motion of stars and planets in the night sky which they can observe themselves, to the expansion of the universe deduced from the latest observations and cosmological models. Students will also be introduced to internet astronomy and the citizen science research platform in astronomy. The course presupposes school level understanding of mathematics and physics.

Course Learning Outcomes: After completing this course, student will gain an understanding of,

- Different types of telescopes, diurnal and yearly motion of astronomical objects, astronomical coordinate systems and their transformations
- Brightness scale for stars, types of stars, their structure and evolution on HR diagram
- Components of solar system and its evolution
- Current research in detection of exoplanets
- Basic structure of different galaxies and rotation of the Milky Way galaxy
- Distribution of chemical compounds in the interstellar medium and astrophysical conditions necessary for the emergence and existence of life
- Internet based astronomy and the collaborative citizen astronomy projects
- India's contribution to astronomy, both in ancient times and in modern era.

Unit 1:   **Hours: 8**

Introduction to Astronomy and Astronomical Scales: History of astronomy, wonders of the Universe, overview of the night sky, diurnal and yearly motions of the Sun, size, mass, density and temperature of astronomical objects, basic concepts of positional astronomy: Celestial sphere, Astronomical coordinate systems, Horizon system and Equatorial system

Unit 2:   **Hours: 6**

Basic Parameters of Stars: Stellar energy sources, determination of distance by parallax

method, aberration, proper motion, brightness, radiant flux and luminosity, apparent and absolute magnitude scales, distance modulus, determination of stellar temperature and radius, basic results of Saha ionization formula and its applications for stellar astrophysics, stellar spectra, dependence of spectral types on temperature, luminosity classification, stellar evolutionary track on Hertzsprung-Russell diagram

Unit 3:   Hours: 7

Astronomical Instruments: Observing through the atmosphere (Scintillation, Seeing, Atmospheric Windows and Extinction). Basic Optical Definitions for Telescopes: Magnification, Light Gathering Power, Limiting magnitude, Resolving Power, Diffraction Limit. Optical telescopes, radio telescopes, Hubble space telescope, James Web space telescope, Fermi Gamma ray space telescope.
Astronomy in the Internet Age: Overview of Aladin Sky Atlas, Astrometrica, Sloan Digital Sky Survey, Stellarium, virtual telescope
Citizen Science Initiatives: Galaxy Zoo, SETI@Home, RAD@Home India

Unit 4:   Hours: 8

Sun and the solar system: Solar parameters, Sun's internal structure, solar photosphere, solar atmosphere, chromosphere, corona, solar activity, origin of the solar system, the nebular model, tidal forces and planetary rings
Exoplanets: Detection methods

Unit 5:   Hours: 12

Physics of Galaxies: Basic structure and properties of different types of Galaxies, Nature of rotation of the Milky Way (Differential rotation of the Galaxy), Idea of dark matter
Cosmology and Astrobiology: Standard Candles (Cepheids and SNe Type1a), Cosmic distance ladder, Olber's paradox, Hubble's expansion, History of the Universe, Chemistry of life, Origin of life, Chances of life in the solar system

Unit 6:   Hours: 4

Astronomy in India: Astronomy in ancient, medieval and early telescopic era of India, current Indian observatories (Hanle-Indian Astronomical Observatory, Devasthal Observatory, Vainu Bappu Observatory, Mount Abu Infrared Observatory, Gauribidanur Radio Observatory, Giant Metre-wave Radio Telescope, Udaipur Solar Observatory, LIGO-India) (qualitative discussion), Indian astronomy missions (Astrosat, Aditya)

References:
Essential Readings:
1) Seven Wonders of the Cosmos, Jayant V Narlikar, Cambridge University Press
2) Fundamental of Astronomy, H. Karttunen et al. Springer
3) Modern Astrophysics, B.W. Carroll and D.A. Ostlie, Addison-Wesley Publishing Co.
4) Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, Saunders College Publishing.
5) The Molecular Universe, A.G.G.M. Tielens (Sections I, II and III), Reviews of Modern

Physics, Volume 85, July-September, 2013

6) Astronomy in India: A Historical Perspective, Thanu Padmanabhan, Springer

Useful websites for astronomy education and citizen science research platform
1) https://aladin.u-strasbg.fr/
2) http://www.astrometrica.at/
3) https://www.sdss.org/
4) http://stellarium.org/
5) https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/
6) https://setiathome.berkeley.edu/
7) https://www.radathomeindia.org/

Additional Readings:
1) Explorations: Introduction to Astronomy, Thomos Arny and Stephen Schneider, McGraw Hill
2) Astrophysics Stars and Galaxies K D Abhyankar, Universities Press
3) Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.
4) Baidyanath Basu, An introduction to Astrophysics, Prentice Hall of India Private Limited.
5) The Physical Universe: An Introduction to Astronomy, F H Shu, University Science Books

GENERIC ELECTIVE (GE – 15): QUANTUM MECHANICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Quantum Mechanics GE – 15	4	3	1	0	Appeared in previous Semester	GE Modern Physics of this course or its equivalent	Physics and Astrophysics

LEARNING OBJECTIVES

The development of quantum mechanics has revolutionized the human life. In this course, the students will be exposed to the probabilistic concepts of basic non-relativistic quantum mechanics and its applications to understand the sub atomic world.

LEARNING OUTCOMES

After completing this course, the students will be able to,
- Learn the methods to solve time-dependent and time-independent Schrödinger equation.
- Characteristics of an acceptable wave function for any sub atomic particle in various potentials.
- Applications of the Schrodinger equation to different cases of potentials namely infinite and finite potential well, step potential, rectangular potential barrier, harmonic oscillator potential.
- Solve the Schrodinger equation in 3-D.
- Understand the spectrum and eigenfunctions for hydrogen atom

SYLLABUS OF GE - 15

THEORY COMPONENT

Unit – I (10 Hours)

Review of Schrodinger wave equation, applicability of operator, eigenvalues, eigenfunction, normalisation, expectation value to various kinds of potential, Superposition Principle, linearity of Schrodinger equation, General solution as a linear combination of discrete stationary states, Observables as operators, Commutator of position and momentum operators, Ehrenfest's theorem. Applicability to various kinds of wave functions

Unit – II (15 Hours)

General discussion of bound states in an arbitrary potential: Continuity of wave function,

boundary conditions and emergence of discrete energy levels. Application to energy eigen states for a particle in a finite square potential well, reflection and transmission across step potential and rectangular potential barrier. Fourier transforms and momentum space wavefunction, time evolution of Gaussian wave packets, Uncertainty principle

Unit – III (10 Hours)
Harmonic oscillator: Energy eigen values and eigen states of a 1-D harmonic oscillator using algebraic method (ladder operators) and using Hermite polynomials. Zero point energy and uncertainty principle.Applications to various kinds of wavefunctions

Unit – IV (10 Hours)
Schrödinger Equation in three dimensions: Probability and probability densities in 3D. Schrödinger equation in spherical polar coordinates, its solution for Hydrogen atom solution using separation of angular and radial variables, Angular momentum operator, quantum numbers and spherical harmonics. Radial wavefunctions from Frobenius method, Orbital angular momentum quantum numbers l and ml, s, p, d shells

References:
Essential Readings:
1) Quantum Mechanics: Theory and Applications, A.Ghatak and S. Lokanathan,6th edition, 2019, Laxmi Publications, New Delhi.
2) Introduction to Quantum Mechanics, D.J. Griffith, 2nd edition, 2005, Pearson Education.
3) A Text book of Quantum Mechanics, P.M. Mathews and K. Venkatesan, 2nd edition,2010, McGraw Hill.
4) Quantum Mechanics, B. H. Bransden and C. J. Joachain, 2nd edition, 2000, Prentice Hall
5) Quantum Mechanics: Concepts and Applications, 2nd edition, N.Zettili, A John Wiley and Sons, Ltd., Publication
6) Atomic Physics, S. N. Ghoshal, 2010, S. Chand and Company

Additional Readings:
1) Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press.
2) Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, 1966, Addison-Wesley Publications
3) Quantum Mechanics, L. I. Schiff, 3rd edition, 2010, Tata McGraw Hill.
4) Quantum Mechanics, R.Eisberg and R.Resnick, 2nd edition, 2002, Wiley
5) Quantum Mechanics, B. C. Reed, 2008, Jones and Bartlett Learning.
6) Quantum Mechanics, W. Greiner, 4th edition, 2001, Springer.
7) Introductory Quantum Mechanics, R. L. Liboff, 4th edition, 2003, Addison Wesley

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Introduction to Embedded System Design GE – 16	4	2	0	2	Appeared in previous semester	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This paper aims to introduce the basic concepts or fundamentals of embedded system design to students not majoring in physics. The course covers the comprehensive introduction to embedded systems, their role and application areas in our daily life. Basic elements needed to design a typical embedded system are discussed to provide the students a broader perspective. Specific applications of embedded systems which are a part of our daily life were discussed. In the end Arduino Uno is introduced.

LEARNING OUTCOMES

Upon completion of this course, students will be able to,

- Learn about an embedded system and how it is different than a general purpose computing system like computer or laptop etc.
- The student should be able to identify various embedded systems available around us in our daily life.
- Classify embedded systems based on generation, complexity and performance, major applications areas etc.
- Explain the domains and areas of applications of embedded systems. The students should be able to get a broader perspective of different embedded systems available in industry, telecom, photography, homes, automobile, aviation and ship industry etc.
- Explain the roles and uses of various components like microcontroller, memory, sensors and actuators, interface types etc. of embedded systems.
- Know the basic characteristics and quality attributes that any typical embedded system must possess.
- This paper is designed in such a way that the students will be able to connect the textbook knowledge with basic design and working of the various embedded systems present in our daily life. By the end of this course the student will have a fairly good idea of embedded systems and the gained knowledge will be helpful in predicting the possible design and working of an unknown system. Arduino Uno is introduced so that students can learn how to use different sensors to control different processes.

SYLLABUS OF GE - 16

THEORY COMPONENT

UNIT – I - Introduction to Embedded Systems   **(3 Hours)**
Embedded systems, historical background, difference between an embedded systems and general computing systems, classification of embedded systems based on generation, complexity and performance, major applications areas, purpose of embedded systems like in data collection/storage/representation, data communication, data/signal processing, monitoring, control, application specific user interface.

Unit – II - Elements of Embedded System   **(6 Hours)**
Core of the embedded system: General purpose and domain specific processors like microprocessors, microcontrollers and digital signal processors, application specific integrated circuits (ASICs), programmable logic devices (PLDs), commercial off-the-shelf components (COTS), reduced instruction set computing (RISC) and complex instruction set computing (CISC), Harvard vs Von-Neumann architecture, different types of memory (RAM, ROM, Storage etc) their classification and different versions,reset circuit, oscillator unit

Unit – III - Peripheral devices, sensors and actuators   **(6 Hours)**
General discussion on light emitting dodes (LEDs), 7-segment LED display, piezobuzzer, push button switch, keypad or keyboard (discuss design using push button switches), relay (single pole single throw), LDR, thermistor, IR sensor, ultrasonic sensor, opto-coupler, DC motors, servo motor, stepper motor (unipolar and bipolar)

Unit – IV - Communication Interface   **(2 Hours)**
Serial and parallel interface, universal serial bus (USB), Infra-red data transfer, bluetooth (BT), Wi-Fi, general packet radio Service (GPRS), 3G, 4G, LTE

Unit – V - Characteristics and quality attributes of an embedded systems   **(3 Hours)**
Characteristics: Application and domain specific,reactive and real time,operation under harsh environments,distributed or stand alone,size and weight,power consumption
Operationaland non-operational attributes: response time,throughput, reliability, maintainability, security, safety, testability and debug-ability, evolvability, portability, cost and revenue

Unit – VI - Applications of Embedded Systems   **(4 Hours)**
General discussion on the design and working of washing machine, refrigerator, microwave oven, automobiles, mobile phones, hearing aid device, electrocardiogram (ECG), AC or TV remote control system, smart watch, digital camera and laser printers etc.

Unit – VII - Introduction to Arduino   **(6 Hours)**
 Pin diagram and description of Arduino UNO, basic programming and applications

References:
Essential Readings:
1) Introduction to embedded system, K.V. Shibu, 1st edition, 2009, McGraw Hill
2) Embedded Systems: Architecture, Programming and Design, R. Kamal, 2008, Tata McGraw Hill
3) Embedded Systems and Robots, S.Ghoshal, 2009, Cengage Learning.
4) Embedded Microcomputer systems: Real time interfacing, J. W. Valvano, 2011, Cengage Learning
5) Embedded System, B. K. Rao, 2011, PHI Learning Pvt. Ltd.
6) Programming Arduino: Getting Started with Sketches, S. Monk, 2nd edition, McGraw Hill

7) Arduino: Getting Started With Arduino and Basic Programming with Projects by E. Leclerc

Additional Readings:
1) The 8051 Microcontroller and Embedded Systems Using Assembly and C, M. A. Mazidi, J. G. Mazidi and R. D. McKinlay, 2nd edition, 2007, Pearson Education
2) Microprocessors and Microcontrollers, K. Kant, 2nd edition, 2016, PHI learning Pvt. Ltd.
3) The 8051 Microcontroller, Ayala, 3rd edition, Cengage learning

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)
- Every student must perform at least six experiments from the following list
- Mandatory exercise for all students: Familiarization with power supply, function generator, CRO/DSO, multimeter, bread board etc. Measure the frequency and amplitude (pp or rms) of a given signal using CRO/DSO. (The purpose is to acquaint the students with these instruments so that they can have a basic understanding of these instruments).

ARDUINO based Experiments:
1) Flashing LEDs ON/OFF after a given delay.
2) Design a simple transmitter and receiver circuit using IR LED and a detector and use it for obstacle detection.
3) Interface a simple relay circuit to switch ON and OFF a dc motor/LED.
4) Interface DC motor to Arduin Uno and rotate it clockwise and anticlockwise.
5) Interface Servo motor to Arduin Uno and rotate it clockwise and anticlockwise for a given angle.
6) Interface an ADC and read the output of the LDR sensor. Display the value on the serial monitor.
7) To design an alarm system using an Ultrasonic sensor.
8) To design a counter/Motion sensor alarm using IR Led and Detector
9) To design a circuit to control ON/OFF of LED light using LDR.
10) To design a circuit to control ON/OFF of a process using a thermistor.
11) To design a thermistor based thermometer.
12) Control the speed of the DC motor using LDR.

References for laboratory work:
1) Arduino Programming: 3 books in 1 - The Ultimate Beginners, Intermediate and Expert Guide to Master Arduino Programming, R. Turner
2) Arduino: Getting Started With Arduino and Basic Programming with Projects, E. Leclerc
3) Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino, M. A. Miller, 1994, McGraw Hill.
4) Electronic Devices and circuit theory, R.L. Boylestadand L.D. Nashelsky, 2009, Pearson
5) Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
6) Modern Electronic Instrumentation and Measurement Tech., Helfrick and Cooper,1990, PHI Learning.

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Nano Physics GE – 17	4	2	0	2	Appeared in previous semester	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

The syllabus introduces the basic concepts of nanomaterials, their synthesis, properties exhibited by them and finally few applications. Various nanomaterial synthesis/growth methods and characterizations techniques are discussed to explore the field in detail. The effect of dimensional confinement of charge carries on the electrical, optical and structural properties will be discussed. Interesting experiments which shape this filed like conductance quantization in 2DEG (Integer Quantum Hall Effect) and coulomb blockade are introduced. The concept of micro- and nano-electro mechanical systems (MEMS and NEMS) and important applications areas of nanomaterials are discussed.

LEARNING OUTCOMES

On successful completion of the course students should be able to,

- Explain the difference between nanomaterials and bulk materials and their property difference.
- Explain various methods for the synthesis/growth of nanomaterials.
- Explain the role of confinement on the density of state function and so on the various properties exhibited by nanomaterials compared to bulk materials.
- Explain the concept of quasi-particles such as excitons and how they influence the optical properties.
- Explain the direct and indirect bandgap semiconductors, radiative and non-radiative processes and the concept of luminescence.
- Explain the structure of 2DEG system and its importance in quantum transport experiments, like integer quantum Hall effect and conductance quantization.
- Explain the conductance quantization in 1D structure and its difference from the 2DEG system.
- Explain the necessary and sufficient conditions required to observe coulomb blockade, single electron transistor and the scope of these devices.
- Explain how MEMS and NEMS devices are produced and their applications.

SYLLABUS OF GE - 17

THEORY COMPONENT

Unit – I – Introduction   **(3 Hours)**
Basic introduction to nano-science and technology - Implications on nanoscience on fields

like Physics, Chemistry, Biology and Engineering, Classifications of nanostructured materials as quantum dots (0D), nanowires (1D), Thin films (2D) and Multilayered materials or super lattices; introduction to properties like mechanical, electronic, optical, magnetic and thermal properties and how they change at nano scale dimensions to motivate students (qualitative only).

Unit – II - Nanoscale Systems   (8 Hours)
Brief review of Schrodinger equation and its applications in- Infinite potential well, potential step and potential box problems, band structure and density of states of 3D and 2D systems in detail and qualitatively for 1D and 0D, confinement of charges in nanostructures their consequences on electronic and optical properties.

Unit – III - Properties of Nano Scale systems   (10 Hours)
Time and length scales (diffusion, elastic and inelastic lengths etc.) of electrons in nanostructured materials, Carrier transport in nanostructures: diffusive and ballistic transport
2D naomaterials: Conductance quantization in 2DEG in GaAs and integer quantum hall effect (semi-classical treatment)
1D nanomaterials: Conductance quantization in 1D structures using split gate in 2DEG system (Qualitative)
0D nanomaterials: Charging effect, Coulomb Blockade effect, Single Electron Transfer (SET) device
Basic understanding of excitons in semiconductors and their consequence on optical properties of the material

Unit – IV - Synthesis of Nanomaterials (Qualitative)   (5 Hours)
Top down and Bottom up approach, Ball milling, Spin Coating
Vacuum deposition: Physical vapor deposition (PVD): Thermal evaporation, Sputtering, Chemical vapor deposition (CVD).
Preparation of colloidal solutions of Metals, Metal Oxide nanoparticles

Unit – V - Applications (Qualitative)   (4 Hours)
Micro Electromechanical Systems (MEMS), Nano-electromechanical Systems (NEMS), Applications of nanomaterials as probes in medical diagnostics and targeted drug delivery, sunscreen, lotions, and paints and other examples to give broader perspective of applications of nanomaterials

References:
Essential Readings:
1) Introduction to Nanotechnology, C. P. Poole and Jr. Frank J. Owens, 1st edition, 2003, Wiley India Pvt. Ltd.
2) Nanotechnology: Principles and Practices, S. K. Kulkarni, 2nd edition, 2011, Capital Publishing Company
3) Introduction to Nanoscience and Technology, K. K. Chattopadhyay and A. N. Banerjee, 2009, PHI Learning Private Limited
4) Introduction to Nanoelectronics, V. V. Mitin, V. A. Kochelap and M. A. Stroscio, 2011, Cambridge University Press
5) Nanotechnology for Dummies, R. Booker and E. Boysen, 2005, Wiley Publishing Inc.
6) Introductory Nanoscience, M. Kuno, 2012, Garland science Taylor and Francis Group
7) Electronic transport in mesoscopic systems, S. Datta, 1997, Cambridge University Press.
8) Fundamentals of molecular spectroscopy, C. N. Banwell and E. M. McCash, 4th edition,

McGrawHill

Additional Readings:
1) Quantum Transport in semiconductor nanostructures, C. Beenakker and H. Van Houten, 1991, available at arXiv: cond-mat/0412664) Open Source
2) Ph.D. thesis, S. Cronewett, 2001, Available as Arxiv
3) Solid State Physics, J. R. Hall and H. E. Hall, 2ndedition, 2014, Wiley

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least six experiments to be performed from the following list

1) Synthesis of metal (e.g. Au/Ag)nanoparticles by chemical route and study its optical absorption properties.
2) Synthesis of semiconductor (CdS/ZnO/TiO$_2$/Fe$_2$O$_3$etc) nanoparticles and study its XRD and optical absorption properties as a function of ageing time.
3) Surface Plasmon study of metal nanoparticles as a function of size by UV-Visible spectrophotometer.
4) Analysis of XRD pattern of given nanomaterial and estimate lattice parameters and particle size.
5) To study the effect of the size nanoparticles on its color.
6) To prepare composite of CNTs with other materials and study their optical absorption/Transmission properties.
7) Growth of metallicthin filmsusing thermal evaporation technique.
8) Prepare a ceramic disc of a given compound and study its XRD/I-V characteristics/ measure its dielectric constant or any other property.
9) Fabricate a thin film of nanoparticles by spin coating (or chemical route) andstudy its XRD and transmittance spectra in UV-Visible region.
10) Prepare thin film capacitor and measure capacitance as a function oftemperature or frequency.
11) Fabricate a pnjunction diode by diffusing Al over the surface of N-type Si/Geand study itsV-I characteristic.
12) Fabricate thin films (polymer, metal oxide) using electro-deposition
13) To study variation of resistivity or sheet resistance with temperature of the fabricated thin films using four probe method.

References for laboratory work:
1) Introduction to Nanotechnology, C.P. Poole and Jr. Frank J. Owens, 1st edition, 2003, Wiley India Pvt. Ltd.
2) Nanotechnology: Principles and Practices, S.K. Kulkarni, 2nd edition, 2011, Capital Publishing Company
3) Introduction to Nanoscience and Technology, K. K. Chattopadhyay and A. N. Banerjee, 2009, PHI Learning Private Limited
4) Nanotechnology for Dummies, R. Booker and E. Boysen, 2005, Wiley Publishing Inc.

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Physics of Detectors GE – 18	4	3	1	0	Appeared in previous Semester	GE Modern Physics of this course or its equivalent	Physics and Astrophysics

LEARNING OBJECTIVES

A detector is necessary for every physical measurement, and experimental physicists must be proficient in detector physics. The course will provide an overview of radiation and particle detectors, as well as how to use them in various experimental physics settings and application fields. The course covers the theory of detectors, their design and operation including electronic readoutsystems and signal processing. The fundamental physics processes for detecting radiation and particles are covered in the course, which include the photoelectric effect, Compton scattering, pair creation, excitation, ionization, bremsstrahlung, Cherenkov radiation, nuclear reactions, and secondary emissions.

LEARNING OUTCOMES

After completion of this course, studentsare expected to be able to,
- Understand the different types underlying fundamental physical processes for the detection of radiation and particles
- Acquire knowledge of design principles and characteristics of different types of detector
- Acquire knowledge of electronic readout systems and signal processing
- Assess the applicability of different types of detectors and detector systems in various fields of physics and applied sciences.

SYLLABUS OF GE - 18

THEORY COMPONENT

Unit – I   **(12 Hours)**
Interaction of Radiation with matter: Interaction of radiation with matter (e.m. charged particles); detection of charged particles in magnetic field and measurement of charge to mass ratio; energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation;gamma ray interaction through matter (photoelectric effect, Compton scattering, pair production); Dependence of electron and photon energy spectrum on materials (increasing Z); neutron interaction with matter

Unit – II   **(8 Hours)**
Introduction to detectors: Basic principle of detector operation and its modes of operation, pulse height spectra, various detector performance parameters: response time, energy resolution, fano factor, efficiency: intrinsic and extrinsic, dead time.

Unit – III (16 Hours)

Detectors:

Gas detectors: Detector gases, gas detector characteristics, different types of detectors: gas filled ionization detectors (ionization chamber), bubble and cloud chambers, proportional counters, multi wire proportional counters (MWPC), Geiger Mueller (GM) counters and avalanche counters, gaseous multiplication detector.

Scintillation detectors: General characteristics, organic scintillators (anthraceneandplastic), inorganic crystals (NaI(Tl), CsI(Tl)), Charge Coupled Devices (CCD)

Photomultipliers: Basic construction and operation, time response and resolution, noise, gain stability; scintillation counter operation

Semiconductor detectors: Doped semiconductors, np semiconductor junction, depletion depth, detector characteristics of semiconductors. silicon and germanium detectors

Neutron detectors (gas-filled, scintillation, and semiconducting): slow and fast neutron detectors

Bolometric detectors: Working principle, characteristics and use of infrared detectors

Unit - IV (5 Hours)

Electronics, signal processing and techniques for data acquisition and analysis: Basic idea of analog and digital signal processing, noise and its types; instrumentation standards for nuclear instruments: NIM, ECL; TTL standards

Data acquisition system: VME and Digital pulse processing system.

Unit - V (4 Hours)

Application of detectors: for particle physics experiments, for nuclear physics, for astrophysics and cosmology, medical physics and imaging, by giving two examples each.

References:

Essential Readings:
1) Radiation detection and measurement, G. F. Knoll, 2010, John Wiley and Sons
2) Principles of radiation interaction in matter and detection, C. Leroy and P.G. Rancoita, 3rd edition, 2011, World Scientific
3) Techniques for Nuclear and Particle Physics experiments, W. R. Leo, 1994, Springer
4) Nuclear Radiation Detectors, S. S. Kapoor and V. S. Ramamurthy, 1st edition, John Wiley and Sons.
5) Physics and Engineering of Radiation Detection, S. N. Ahmed, 2007, Academic Press Elsevier
6) Semiconductor detectors: New developments, E. Gatti and P. Rehak, 2002, Springer

Additional Readings:
1) Radiation Detection for Nuclear Physics Methods and industrial applications, D. Jenkins
2) Advanced Nuclear Radiation Detectors Materials, processing, properties and applications, A. K.Batra, IOP Publishing
3) Measurement and Detection of Radiation, N.Tsoulfanidiset al., 4th edition, T and F CRC
4) Principles of nuclear radiation detection, G. G. Eichholz and J. W. Poston, CRC
5) Introduction to Nuclear Radiation Detectors: 2, Laboratory Instrumentation and Techniques, P. Ouseph, Springer
6) Detectors for Particle Radiation, K.Kleinknecht, Cambridge
7) Particle Detectors, C.Grupen, Cambridge
8) Handbook of Particle Detection and Imaging, C.Grupen and I. Buvat

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Nuclear and Particle Physics GE – 19	4	3	1	0	Appeared in previous Semester	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This course imparts the understanding of the sub atomic particles and their properties; introduces various nuclear phenomena and their applications, interactions of basic building blocks of matter through fundamental forces, the inherent discrete symmetries of particles and complements each and every topic with applications and problems.

LEARNING OUTCOMES

After completion of this course, studentsare expected to have an understanding of,

- Nuclear charge and mass density, size, magnetic and electric moments
- Theoretical principles and experimental evidences towards modelling the nucleus
- Kinematics of nuclear reactions and decays
- Energy loss of radiation during propagation in medium
- Principles of nuclear detection technique
- Classification of fundamental forces based on their range, time-scale and mediator mass.
- Scattering cross-sections of 2 to 2 processes and their inherent symmetries.
- Angular and energy distributions for three body decay process.
- Discrete symmetries of nature and associated conservation laws
- Colour triplet quarks and anti-quarks as constituents of observed colour singlet baryons and mesons.

SYLLABUS OF GE 19

THEORY COMPONENT

Unit – I (5 Hours)
General properties of nuclei: Constituents of nucleus and their Intrinsic properties: quantitative facts about mass, radii, charge density, matter density, binding energy, N/Z plot, angular momentum, parity, magnetic moment, electric moments.

Unit – II (5 Hours)
Nuclear models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, evidence for nuclear shell structure and the basic assumptions of shell model, magic numbers.

Unit – III (7 Hours)

Radioactivity decay: Decay rate and equilibrium (secular and transient)
(a) Alpha decay: basics of α-decay processes, Gamow factor, Geiger Nuttall law, α-decay spectroscopy, decay Chains.
(b) β-decay: energy kinematics for β-decay, β-spectrum, positron emission, electron capture, neutrino hypothesis.
(c) Gamma decay: Gamma ray emission from the excited state of the nucleus and kinematics, internal conversion.

Unit – IV   **(5 Hours)**
Nuclear reactions: Kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct reaction, Coulomb scattering (Rutherford scattering).

Unit – V   **(8 Hours)**
Interaction of nuclear radiation with matter: Energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation; Gamma ray interaction through matter Detector for nuclear radiations: Basics of types of detectors: gas detectors, scintillation detector, semiconductor detector(principle, schematics of construction and working)

Unit – VI   **(15 Hours)**
Particle Physics: Overview of particle spectrum and their interactions in the Standard Model;range, time-scale and relative strength of interactions;interactions at a distance mediated by virtual particles (Exchange Force)
Kinematics for 2 -> 2 scattering processes and crossing symmetries of scattering amplitudes; angular and energy distributions of decaying particles in 1-> 3 decay processes (muon decay/beta decay); identification of invisibles (neutrinos) from energy and transverse momentum distributions
Lepton and Baryon quantum numbers;isospin, strangeness and hypercharge; Gell-Mann-Nishijima formula;parity and charge conjugation of a particle state; time reversal and general CPT theorem
Valence quark model of Murray Gell-Mann and Yuval Ne'eman, current and constituent masses of quarks, flavor symmetry isospin triplets, baryon octet, decuplet and meson octet; existence of Δ^{++} baryon as a clue for necessity of colour quantum number;evidence for colour triplet quarks from e^+e^- annihilation experiment;confinement of quarks, antiquarks and gluons in hadrons
High energy scattering experiments at linear and circular colliders, inelastic collisions at hadron colliders;elastic and inelastic neutrino-nucleus scattering experiments

References:
Essential Readings:
(A) For Nuclear Physics
1) Basic ideas and concepts in nuclear physics: An introductory approach, K. Heyde, 3rd edition, 1999, IOP Publication
2) Introductory Nuclear Physics, K. S.Krane, 2008, Wiley-India Publication
3) Nuclear Physics, S. N.Ghoshal, 1stedition, 2010, S. Chand Publication
4) Nuclear Physics: Principles and applications, J. Lilley, 2006, Wiley Publication
5) Concepts of Nuclear Physics, B. L. Cohen, 1974, Tata McGraw Hill Publication
6) Radiation detection and measurement, G. F. Knoll, 2010, John Wiley and Sons

(B) For Particle Physics
1) Modern Particle Physics, M. Thompson, 2013, Cambridge University Press

2) Particles and Nuclei: An Introduction to the Physical Concepts, B.Povh, K.Rith, C.Scholz, F.Zetsche and W.Rodejohann, 2015, Springer-Verlag
3) An Introductory Course of Particle Physics, P. B. Pal, 2015, CRC Press
4) Introduction to High Energy Physics, D. H. Perkins, 4th edition, 2000, Cambridge University Press
5) Introduction to elementary particles, D. J. Griffiths, 2008, Wiley
6) Quarks and Leptons, F. Halzen and A. D. Martin, 1984, John Wiley

Additional Readings:
References for Tutorial
1) Problems and Solutions in Nuclear and Particle Physics, S.Petreta, 2019, Springer
2) Schaum's Outline of Modern Physics, 1999, McGraw-Hill
3) Schaum's Outline of College Physics, E. Hecht, 11th edition, 2009, McGraw Hill
4) Problems and Solutions on Atomic, Nuclear and Particle Physics, Yung-Kuo Lim, 2000, World Scientific
5) Nuclear Physics "Problem-based Approach"including MATLAB, H. M. Aggarwal, 2016, PHI Learning Pvt. Ltd

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Atomic and Molecular Physics GE – 20	4	3	1	0	Appeared in previous Semester	GE Modern Physics and GE Quantum Mechanics of this course or their equivalent	Physics and Astrophysics

LEARNING OBJECTIVES

This course introduces the basic concepts of atomic, molecular and nuclear physics to an undergraduate student. Advanced mathematics is avoided and the results of quantum mechanics are attempts to explain, or even to predict, the experimental observations of spectroscopy. The student will be able to visualize an atom or molecule as a physical entity rather than a series of mathematical equations.

LEARNING OUTCOMES

On successful completion of the module students should be able to elucidate the following main features.
- Stern-Gerlachexperiment, electron spin, spin magnetic moments
- Space quantization and Zeeman effect
- Spectral notations for atomic and molecular states and corresponding term symbols
- Understanding of atomic spectra and molecular spectra
- Basic principle of Raman spectroscopy and Franck Condon principle
- To complete scientific potential lies on the way we are able to interpret the fundamental astrophysical and nuclear data. This acquired knowledge will be a common base for the areas of astrophysics, nuclear, medical, geology and other inter-disciplinary fields of Physics, Chemistry and Biology. Special skills required for the different fields will be enhanced.

SYLLABUS OF GE 20

THEORY COMPONENT

Unit – I – Atomic Physics (23 Hours)
One-electron atoms: Degeneracy of energy levels and selection rules, modes of relaxation of an excited atomic state,line intensities and the lifetimes of excited states, line shapes and widths
Fine structure of hydrogenic atoms: Shifting of energy levels, splitting of spectral lines, relativistic correction to kinetic energy, spin-orbit term, Darwin term, fine structure spectral lines, Lamb shift (qualitative idea)
Atoms in external magnetic fields: Larmor'stheorem, Stern-Gerlach experiment, normal Zeeman effect,Paschen Back effect, and anomalous Zeeman effect, g-factors
Two and multi-electron systems: Spin multiplicity, singlet and triplet states and selection rules in helium atom, central field approximation, Aufbau and Pauli exclusion principle,

Slater determinant, LS and JJ coupling scheme (equivalent and non-equivalent electrons), term symbols and Hund's rule,Lande' interval rule
Qualitative Discussion of: Lamb shift and Auger effect.

Unit – II - Molecular Physics   **(22 Hours)**
Electronic states of diatomic molecules: Linear combination of atomic orbitals (LCAO), bonding and antibonding orbitals; 'gerade', 'ungerade', molecular orbitals and the ground state electronic configurations for homo and hetero-nuclear diatomic molecules, classification of molecular excited states of diatomic molecule, Vector representation of Orbital and electron spin angular momenta in a diatomic molecule, The Born-Oppenheimer approximation, Concept of Potential energy curve for a diatomic molecule, Morse potential. The Franck-Condon principle
Molecular Spectra of diatomic molecule: Rotational Spectra (rigid and non-rigid rotor), Vibrational Spectra (harmonic and anharmonic), Vibration-Rotation Spectrum of a diatomic molecule, Isotope effect, Intensity of spectral lines
Raman Effect: Classical Theory (with derivation) of Raman effect, pure rotational Raman Lines, Stoke's and Anti-Stoke's Lines, comparison with Rayleigh scattering
Idea of spin resonance spectroscopy (Nuclear Magnetic Resonance, Electron Spin Resonance) with few examples, estimation of magnetic field of the Sun.

References:
Essential Readings:
1) Physics of Atoms and Molecules, B. H. Bransden and C. J. Jochain, 2nd edition, Pearson
2) Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, 1994, Tata McGraw – Hill
3) Atomic physics, J. B. Rajamand foreword by Louis De Broglie, 2010, S. Chand and Co.
4) Atoms, Molecules and Photons, W. Demtroder, 2nd edition, 2010, Springer
5) Atomic, Nuclear and. Particle Physics. Compiled by. The Physics Coaching Class. University of science and Technology of China,edited By Yung-Kuo Lim. World scientific.
6) Atomic Physics, S.N. Ghoshal, 2019, S. Chand Publication
7) Introduction to Spectroscopy, D. L. Pavia, G. M. Lampman, G. A. Kriz and J. R. Vyvyan, 5th edition, 2014, Brookes/Cole

Additional Readings:
1) Basic Atomic and Molecular Spectroscopy, J. M. Hollas, Royal Society of Chemistry
2) Molecular Spectra and Molecular Structure, G. Herzberg
3) Introduction to elementary particles, D. J Griffiths, 2008, Wiley
4) Atomic and molecular Physics, R. Kumar, 2013, Campus Book Int.
5) The Fundamentals of Atomic and Molecular Physics, Undergraduate Lecture Notes in Physics, 2013, Springer