CENTRAL UNIVERSITY OF SOUTH BIHAR

Master of Science (M.Sc.) Physics Programme

Syllabus

(Effective from Academic Session 2020-2021)

Department of Physics

SCHOOL OF PHYSICAL AND CHEMICAL SCIENCES

SCHOOL OF PHYSICAL & CHEMICAL SCIENCES

Department of Physics

Department of Physics, under the umbrella of School of Physical & Chemical Sciences, has been providing support to the undergraduate programs of Central University of South Bihar (CUSB) since its inception. The M.Sc. Degree Program in Physics was launched from the academic session 2018-19 with the intake of 35 students and from academic session 2019-20, the department is running the Ph.D. programme in various frontier areas of physics such as Nuclear & Particle, High Energy Physics, Astroparticle Physics, Low energy neutrino Physics, Dark Matter, Detector development and Data Acquisition System (DAQ), Experimental condense matter Physics and Material Science, Superconductivity (Theory), Nano-science and technology (Theory), Metallic glasses (Experimental), Molecular Motors, Molecular Spintronics, Two-dimensional superconductivity, Material synthesis, crystal growth and characterization (Piezo, ferro, semiconductor and NLO), Synthesis & Characterization of Nano material, magnetic and hydrogen storage properties, Noncommutativity and deformed special relativity. In addition, from the upcoming session 2020-21, the department is going to start one major undergraduate programme namely B. Sc. Honours in Physics – a three year degree course as per UGC CBCS norms. From the same academic session department is going to offer two specializations in postgraduate programmes such as Material Science, and Nuclear & Particle Physics.

The Department of Physics is committed to engage in high quality research and in the pursuit of excellence in teaching. The faculty members of the department are actively involved in cutting-edge theoretical and experimental research in challenging areas as mentioned above. To promote interdisciplinary research for solving grand challenges facing our society, the department has established both intra-university as well as inter-institutional collaborations with laboratories in India and overseas. The department of physics has active national and international research collaborations.

Ph.D. in Physics

The broad areas of research in the department of Physics are hard/soft condensed matter physics, spectroscopy, nanoscience and nanotechnology, materials science, and Nuclear and Astroparticle Physics. In due course we will also open research areas related to computational physics, theoretical biophysics, and space physics. All the students will be required to successfully complete a course work before beginning the research towards their Ph.D. thesis. The tentative course work structure, subjected to the approval from the Board of Studies, is as follows:

Course Code	Course Title	Credits
Core	Research Methodology	4
Core	Theoretical and Experimental Techniques of Physics Research	4
Core	Review, Report and Seminar	2
Core	Research and Publication Ethics (RPE)	2

Course Title: Research Methodology			
Course Code	PHDPHY1001C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L)

Unit :1

Research objectives: Types of research, Development of a research question; Science, pseudoscience and rationalism; Physical science and metaphysics; Literature survey, Identification of knowledge gaps and a research problem; Concept of novelty, Formulation and implementation of a research plan; Serendipity, creativity, discovery and innovation.

Research process and tools: Design of experiments, testing and characterization; Measurement - Standardization, calibration and sampling; Primary and secondary data; Computer programming, theory, modelling and simulation; Data acquisition, processing, observation, critical analysis and interpretation; Presentation of data; Reliability and reproducibility.

(15 Lectures)

Unit:2

Computer applications and tools: Software for documentation, graphs, graphics, drawing and presentation.

Search engines and databases: Web literature search; International standards, reference data and constants.

Library system: Physical cataloguing of books and journals; Online catalogue search; Subscribed books and journals.

Good laboratory practices: Organization and cleanliness; Maintenance of laboratory records; Biological, chemical, electrical and fire safety; Safe disposal of hazardous materials; Upholding environmental and human concerns in planning and conducting experiments; Government regulations.

(15 Lectures)

Unit :3

Communicating research results: Journal paper – types of available publishing services; Research proposal, Report, Thesis; Presentation in Seminar and conference; Journal abbreviations, Bibliography standards; Indices of quality assessment of publications.

Statistical techniques: Mathematical tools for analysis, Statistical data treatment and evaluation; Probability and probability distributions; Sampling and sampling designs, Data analysis, Testing of hypothesis, statistical tests and analysis, Data interpretation, multivariate analysis, Model building.

(15Lectures)

Unit:4

Analytical and numerical techniques: Mean deviation, Root mean square deviation, Histogram, Skewness, Kurtosis, Moments, Variance, Chi-square, Correlation, Factor analysis, Mean square weighted deviation, Regression, Time series analysis

Statistical and graphical packages: MS Excel, MATLAB, Microcal Origin / Sigma plot, gnu plot, xmgr – Key Features; Developing algorithms and applications, Tex.

(15 Lectures)

Text Books:

1. Research Methodology: The Aims, Practices and Ethics of Science, P. Pruzan, Springer, 2016
2. Research Methods for Science, M. P. Marder, Cambridge University, 2011
3. Fundamentals of Research Methodology and Statistics, Y.K. Singh, New Age, 2006

Reference Books:

1. Research Methodology: An Introduction for Science and Engineering Students; Melville
2. and Goddard, Juta, 1996
3. Research Methods in Science and Engineering, Scott A. Gold, CRC Press, 2016

Course Title: Theoretical and Experimental Techniques of Physics Research			
Course Code	PHDPHY1002C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L)

Unit: 1

Quantum Mechanics: Schrödinger Picture, **Time independent perturbation theory**: Theory and an example; S**cattering theory**: Quantum theory, Partial wave analysis (one example), Born Approximation and its validity (One example); P**ath integral formulation**: propagator, Schrödinger wave equation from path integral, eg: free particles; Introduction to second quantization; Q**uantum field theory**: quantization of scalar field and Dirac field.
***Condensed Matter Physics**:* **Electronic Structure Calculation:** Hartree-Fock Theory, Introduction to Density Functional Theory; **Correlated Electron States:** Mott Transition, Hubbard Model, Magnetic impurities and Kondo Model; **Quantum Hall effect:** Integer and fractional Hall Effect, Laughlin wave function; **Magnetism:** Mean field approximation for Heisenberg Hamiltonian model for Ferromagnetism.

(15 Lectures)

Unit: II
High Energy Physics: Introduction to relativistic kinematics, Review of Experimental methods: fixed target and collider experiments, Introduction of four forces and interactions, Feynman diagrams Basics of quantum electrodynamics: Glashow-Salam-Weinberg model,
Standard Model Physics.
Nonlinear Optics: Nonlinear wave propagation in Anisotropic media; Second Harmonic Generation (SHG); Phase Matching Techniques; Three-Wave Interactions; Third Harmonic Generation (THG); Density Matrix and Perturbation approach to Nonlinear susceptibility.

(15 Lectures)

Unit: III
Vacuum Generation and Measurement Techniques: Introduction to vacuum, gas law; Rotary vane pump, Turbomolecular pump, Cryo pump; Pirani gauge, Penning gauge.
Fundamentals of Synthesis and Fabrication of Materials: Classification of powders; Synthesis of powders: Sol-gel, Hydrothermal, Combustion techniques; Synthesis of thin films: Spincoating, Dip coating, Thermal and electron beam evaporation, Pulsed laser deposition; General concept of lithography, Photolithography, Electron beam lithography; Clean room. **Introduction to Basic Measurements and Characterization Techniques:** ***Study of Crystal Structure****:* X-ray diffraction (XRD), Transmission Electron diffraction (TED), ***Microscopic Techniques****:* Optical Microscopes (Bright field, Confocal, Super-resolution), Scanning Electron Microscope, Transmission Electron Microscope, Scanning Probe Microscopes.

(15 Lectures)

Unit: IV
Spectroscopic Techniques*:* UV-Vis, Fluorescence, IR and FTIR, Photo-Acoustic, Laser Induced Breakdown, Raman, Twyman-Green interferometer as a special case of Michelson Interferometer for testing of optical components, Lateral shearing interferometers and its applications such as testing. Collimation of a lens, laser speckle techniques and its applications. **Surface and Compositional Analysis Methods**: EDAX, XPS. **Dielectric Characterization**: Complex impedance spectroscopy, Analysis of Nyquist plot, Various RC network schemes, Analysis of CV curves, ac conductivity, Charging-discharging cycle of capacitors. **Electrochemical Measurements**: Different potentiometric /galvanometric techniques.
Methods for studying electrical, magnetic, thermal properties. **Accelerator and Fusion Techniques:** Pelletron, Linear accelerator, Cyclotron, Synchrotron, Tokamac; Applications in High energy physics, Materials science and Particle therapy. **Low Temperature Methods :** Temperature measurement and control; Cryostats and cooling methods.

(15 Lectures)

Text Books:

1. Handbook of Vacuum Science and Technology; Hoffman, Singh and Thomas; Academic Press, 1998.
2. Nanostructures and Nanomaterials **-** Synthesis, Properties and Applications; Guozhong Cao, World Scientific, 2004
3. Thin Film Phenomena; Chopra; McGraw-Hill; 1969

4. ASM Handbook: Volume 10: Materials Characterization; Crankovic; ASM International;1986
5. Surface Characterization Methods: Principles, Techniques and Applications; Milling; CRC Press; 1999

Course Title: Review, Report and Seminar			
Course Code	PHDPHY1003C02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L)

Course Title: Research and Publication Ethics (RPE)			
Course Code	PHDPHY1003C02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L)

Research ethics: Ethics code of American Psychological Association; Collaboration, cooperation and teamwork; Research outcome; Intellectual property right, Copy-right, patent**,**
fundamentals of patent filing; Usage of pirated version of literatures and software; Plagiarism – Case Studies, Web based verification.

References:

1. Research Methods for Science, M. P. Marder, Cambridge University, 2011
2. Fundamentals of Research Methodology and Statistics, Y.K. Singh, New Age, 2006

M.Sc. in Physics

The objectives of this program are to cater and to meet the needs and aspirations of contemporary M.Sc. Physics students. It is tailored to incorporate the essential ingredients of multifaceted education and research for this rapidly changing world. This program aims to (i) provide the much needed and strong foundation in Physics so that students can develop the ability to apply the knowledge of Physics in any allied fields, (ii) help students to develop programming proficiency with high end software for both computation and automation, (iii) give students an opportunity to use advanced laboratory equipment to get acquainted with them, (iv) present a platform to students for training in both mechanical and electronic hardware for basic and applied research, (v) offer necessary soft skills to the students to build their professional career, (vi) to make the students well aware about the radiation safety and precautions that will help the society to make their life better, (vii) to enhanced their knowledge in the area of nuclear and particle physics that will help in making their contribution in country's nuclear energy and national security and safety programmes.

List of Courses in M.Sc. Physics from Academic Session 2020-2021 (96 Credits)

Course Code	Course Title	Credit		
Semester-I		L	T	P
MSPHY1001C04	Mathematical Physics	4	0	0
MSPHY1002C04	Classical Mechanics	4	0	0
MSPHY1003C04	Quantum Mechanics	4	0	0
MSPHY1004C04	General Physics Lab. – I	0	0	4
MSPHY1005E04	Electronics	4	0	0
MSPHY1006E04	Experimental Techniques	4	0	0
MSPHY1007E04	Biography of Indian Scientists	2	0	0
	Elective – I (From other department)	4	0	0
	Total Credit	30		
Semester - II		L	T	P
Course Code	Course Title	Credit		
MSPHY2001C04	Thermodynamics and Statistical Physics	4	0	0
MSPHY2002C04	Classical Electrodynamics and Relativity	4	0	0
MSPHY2003C04	General Physics Lab. – II	0	0	4
MSPHY2004C04	Atomic and Molecular Physics	4	0	0
MSPHY2005C04	Elementary Solid State Physics	2	0	0
MSPHY2006C04	Elementary Nuclear & Particle Physics	2	0	0
MSPHY2007E04	Advanced Quantum Mechanics	4	0	0

MSPHY2008E04	Advanced Mathematical Physics	4	0	0
MSPHY2009E04	Introduction of Ancient Indian Sciences	4	0	0
	Total Credit		**32**	
Semester-III (Specialization in Condensed Matter Physics)		**L**	**T**	**P**
Course Code	**Course Title**	**Credit**		
MSPHY3001C04	Condensed Matter Physics	4	0	0
MSPHY3002C04	Solid State Devices	4	0	0
MSPHY3003C04	Solid State Physics Lab - I	0	0	4
MSPHY3004E04	Materials Science	4	0	0
MSPHY3005E04	Crystal Growth and Characterizations	2	0	2
MSPHY3006E04	Crystallography Crystal Structure and Diffraction Techniques	2	0	2
MSPHY3007E04	Fundamentals of nanoscience and nanotechnology	4	0	0
MSPHY3008E02	Physics of Dielectic and Ferroelectric Materials	2	0	0
MSPHY3009E02	X-ray Spectroscopy	2	0	0
MSPHY3010E02	Diffusion in Solids	2	0	0
MSPHY3011E04	Fundamentals of Scanning Probe Microscopy	4	0	0
	Elective - III (from other Department)	4	0	0
	Total Credit		**42**	
Semester-IV (Specialization in Condensed Matter Physics)		**L**	**T**	**P**
Course Code	**Course Title**	**Credit**		
MSPHY4001C04	Advanced Condensed Matter Physics	4	0	0
MSPHY4002C04	Dissertation	4	0	0
MSPHY4003C04	Solid State Physics Lab - II	0	0	4
MSPHY4004E04	Physics of Magnetism and Spintronics	4	0	0
MSPHY4005E04	Alloy Design and Development	2	0	2
MSPHY4006E04	Material Synthesis and Processing	2	0	2
MSPHY4007E04	Renewable Energy	4	0	0
MSPHY4008E04	Carbon Nanostructres and Their Properties	2	0	2
MSPHY4009E04	Biomedical Instrumentation	4	0	0
MSPHY4010E04	Industrial Process Control	4	0	0

MSPHY4011E04	Nanoelectronics	4	0	0
	Total Credit	**44**		
Semester-III (Specialization in Nuclear and Particle Physics)		**L**	**T**	**P**
Course Code	**Course Title**	**Credit**		
MSPHY3101C04	Advanced Nuclear Physics	4	0	0
MSPHY3102C04	Nuclear & Particle Physics Lab. – I	0	0	4
MSPHY3103C04	Advanced Particle Physics	4	0	0
MSPHY3104E04	Introduction of Astrophysics	4	0	0
MSPHY3105E04	Nuclear Reactor Physics	4	0	0
MSPHY3106E04	Statistical Analysis Techniques in Nuclear and Particle Physics	4	0	0
MSPHY3107E04	Radiation Safety	2	0	0
MSPHY3108E04	Neutrino Physics	2	0	0
	Elective – I (from other department)	4	0	0
	Total Credit	**32**		
Semester - IV (Specialization in Nuclear and Particle Physics)		**L**	**T**	**P**
Course Code	**Course Title**	**Credit**		
MSPHY4101C04	Experimental Techniques in Nuclear and Particle Physics	4	0	0
MSPHY4102C04	Dissertation	0	0	4
MSPHY4103C04	Nuclear & Particle Physics Lab. – II	0	0	4
MSPHY4104E04	Particle Accelerator Physics	4	0	0
MSPHY4105E04	Data Analysis and Simulation in particle Physics	4	0	0
MSPHY4106E04	General Theory of Relativity	4	0	0
MSPHY4107E04	High Energy Cosmic Rays	2	0	0
MSPHY4108E04	Dark Matter Physics	0	0	0
	Total Credit	**26**		

Master of Science (M.Sc.) Physics Programme

Detailed Syllabus

(Effective from Academic Session 2020-2021)

Methods of Content Interaction	Mainly: Lectures and Tutorials; Additionally: Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.

SEMESTER - I

Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)

Course Title: Mathematical Physics			
Course Code	MSPHY1001C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L)

UNIT I:
Linear vector spaces and operators: Vector spaces and subspaces, Linear dependence and independence, Inner product, Orthogonality, linear operators, Matrix representation, Similarity transformations, Characteristic polynomial of a matrix, Eigen values and eigenvectors, Self adjoint and Unitary transformations, Eigen values and eigenvectors of Hermitian and Unitary transformations, diagonalization.

(20 Lectures)

UNIT II:
Vector analysis and curvilinear co-ordinates: Gradient, Divergence and Curl operations, Vector Integration, Gauss' and Stokes' theorems, Curvilinear co-ordinates, Gradient, Curl, divergence and Laplacian in spherical polar and cylindrical polar co-ordinates. Definition of tensors, contravariant and covariant components of tensors.

(20 Lectures)

UNIT III:
Ordinary differential equations and Special Functions: Linear ordinary differential equations, Series solutions – Frobenius'method, Series solutions of the differential equations of Bessel, Legendre, Leguerre and Hermite polynomials.

(20 Lectures)

References

1. Mathematical Methods of Physics - J. Mathews and R. L. Walker, Second Edition,
2. Addison-Wesley.
3. Mathematical Methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012
4. Matrices and Tensors in Physics - M. R. Spiegel, Schaum Series
5. Linear Algebra – Seymour Lipschutz, Schaum Outlines Series
6. Matrices and Tensors in Physics - A.W. Joshi, Wiley Eastern Ltd, 1975
7. Vector Analysis - M. R. Spiegel, Schaum Series
8. Introduction to Dynamics – I. Percival and D. Richards, Cambridge University Press.

Course Title: Classical Mechanics			
Course Code	MSPHY1002C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L)

UNIT I:
System of particles: Center of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, energy and angular momentum. Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the second kind, uniqueness of the Lagrangian, Simple applications of the Lagrangian formulation: 1. Single free particle in (a) Cartesian co-ordinates, (b) plane polar co-ordinates; 2. Atwood's machine; 3.bead sliding on a uniformly rotating wire in a forcefree space; 4. Motion of block attached to a spring ; 5. Simple pendulum. Symmetries of space time: Cyclic coordinate, Conservation of linear momentum, angular momentum and energy.

(15 Lectures)

UNIT II:
Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion), equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force).

Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering, center of mass and laboratory co-ordinate systems, transformations of the scattering angle and cross-sections between them. Motion in non-central reference frames: Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum.

(15 Lectures)

UNIT III:
Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia, classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body.

Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a

system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula.

(15 Lectures)

UNIT IV:
Hamiltonian formulation: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Examples of (a) the Hamiltonian of a particle in a central force field, (b) the simple harmonic oscillator, cyclic co-ordinates and conservation theorems, derivation of Hamilton's equations from variational principle. Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton-Jacobi method

(15 Lectures)

References

1. Classical mechanics, H. Goldstein, C. Poole, J. Saflco, 3rd edition, Pearson Education Inc. (2002).
2. Classical mechanics, K. N. Srinivasa Rao, University Press (2003).
3. Classical mechanics, N. C. Rana and P. S. Joag, Tata McGraw-Hill (1991).

4. Classical dynamics of particles and systems, J. B. Marian, Academic Press (1970)

5. Introduction to classical mechanics, Takwale and Puranik, Tata McGraw-Hill (1983).

6. Classical mechanics, L. D. Landau and E. M. Lifshitz, 4th edition, Pergamon press (1985).

Course Title: Quantum Mechanics			
Course Code	MSPHY1003C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L)

UNIT I: Introductory concepts of Quantum Mechanics

Wave-particle duality, electron diffraction, Wave packets, Gaussian wave packet, Spreading of Gaussian wave packet, Heisenberg uncertainty principle for position and momentum, Schrodinger equation, conservation of probability, probability interpretation of wave function, expectation values, Ehrenfest theorem, measurement in quantum theory, time independent Schrodinger equation, stationary states, momentum space representation.

(15 Lectures)

UNIT II: One Dimensional and Three Dimensional Problems

One Dimensional: Particle in a box – simple harmonic oscillator - Square well potential – Barrier penetration.
Orbital angular momentum and spherical harmonics, Orbital angular momentum commutation relations, Eigen values and eigen functions, General operator algebra of angular momentum operators J_x, J_y, J_z. Ladder operators, Eigen values and eigenkets of J^2 and Jz, Matrix representations of angular momentum operators, Pauli matrices, Addition of angular momentum, Clebsch-Gordan coefficients, computation of Clebsch-Gordan coefficients in simple cases ($j_1 = j_2=1/2$).

Three Dimensional: Central potential, separation of variables in the Schrodinger equation, Particle in a Spherical well, the radial equation. The Hydrogen atom.

(15 Lectures)

UNIT III: General formalism of quantum theory

Operator formalism: Hilbert space and observables, linear operators and observables, Dirac notation, degeneracy and simultaneous observables, generalized uncertainty principle for two non-commuting observables, Unitary dynamics, projection operators and measurements, time-dependence of observables: Schrodinger, Heisenberg and interaction pictures, Simple harmonic oscillator by operator method.
Identical particles: Exchange degeneracy, Symmetrization Postulate, Constructing symmetric and antisymmetric states, system of identical non-interacting particles, the Pauli's exclusion principle and the Periodic table

(15 Lectures)

UNIT-IV: Approximation methods
Time-independent perturbation theory for non- degenerate and degenerate levels - Application to ground state of an harmonic oscillator and Stark effect in Hydrogen - Variation method -Application to ground state of Helium atom - WKB approximation - WKB quantization rules, Applications in the theory of alpha-decay and field emission of electrons.

(15 Lectures)

References:

1. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
2. Quantum Mechanics Concepts and Applications- Nouredine Zettile, Second Edison, John Wiley and Sons. 2009
3. Quantum Mechanics Vol I & II – C. Cohen-Tannoudji, B. Diu and F. Laloe, Second Edition, Wiley Interscience Publication, 1977.
4. Quantum Mechanics – E. Merzbacher, John Wiley and Sons, 1998.
5. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
6. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
7. Principles of Quantum Mechanics - R. Shankar, Second Edition, Springer, 1994.

8. Quantum Mechanics- L.I. Schiff, Third Edition, Mc Graw Hill Book Company, 1955.
9. Quantum Physics – S. Gasiorowicz, John Wiley and Sons.

Course Title: General Physics Lab – 1			
Course Code	MSPHY1004C04	**Credits**	4
L + T + P	0 + 0 + 4	**Contact Hours**	120 (P)

❖ **List of Experiments:**

1. To study Hydrogen spectrum and determine Rydberg's constant with the help of spectrometer diffraction grating and a Hydrogen spectrum tube.
2. To determine wavelength of sodium light by Fresnel's Biprism method.
3. To determine specific rotation of sugar using polarimeter.
4. To measure radius of curvature of a Plano-convex lens using Newton's ring apparatus.
5. Determination of wavelength of sodium light using Newton's ring apparatus.
6. To determine wavelength of sodium light by diffraction grating using spectrometer.
7. To verify Norton's Theorem and to find equivalent current source circuit.
8. To verify Theivenin's theorem and to find equivalent voltage source circuit.
9. To verify superposition and maximum power transfer theorem.
10. To study transient response in R-C circuit.
11. Measurement of frequency and phase using Lissajous figure.
12. To study applications of operational amplifier as adder, substractor and buffer.
13. Construction and verification of Up / Down, synchronous/ asynchronous, ripple decade counters and 4 bits universal shift register.
14. To measure the charge to mass ratio (e/m) of the electron.
15. To find speed of sound using resonance column.
16. To study and construct different type of holographic photographs.
17. To verify Faraday and Lenz's law of induction by measuring the induced voltage as function of time.
18. To determine the speed of light in air.

❖ Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Electronics			
Course Code	MSPHY1005E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L)

UNIT I:
Physics of devices: p-n junction, abrupt junction, band structure, thermal equilibrium, depletion region, depletion capacitance, current and voltage characteristics, **Bipolar Junction Transistor (BJT):** band structure - transistor action – static characteristics. **Field Effect Transistors:** JFET structure, working, characteristics; MOS structure; MOSFET working, MOSFET characteristics, width of depletion region, junction capacitance-threshold voltage. Metal semiconductor contacts – ohmic and Schottky contacts. **Photo-electronic Devices:** Principle of operation, photoconductor – efficiency, current gain, response time. Effect of light on I-V characteristics of a junction photo device, principle and working of a photodiode, Light emitting devices, principle , working and factors affecting the efficiency of LED.

(15 Lectures)

UNIT II:
Boolean Expressions: Boolean laws and theorems, simplification of SOP equations, Simplification of POS equations, Simplification using Karnaugh Map technique (4 variables)- conversion of binary to Grey code. **Flip flops:** Latch using NAND and NOR gates- RS flip flop , clocked RS flip flop, JK flip flop, JK master slave flip flop - racing –Shift Registers basics - Counters: Ripple counters truth table-timing diagram, Synchronous counters-truth table-timing diagram, Decade counter. **Visual displays**: Single-element displays, seven-segment displays, decoder logic. **Digital to Analog converters:** ladder and weighted resistor types. Analog to digital Converters-counter method, successive approximation and dual slope converter. Application of DACs and ADCs.

(15 Lectures)

UNIT III:
Digital Data Communication Standards: Serial communications: RS232, handshaking implementation of RS232 on PC; Universal Serial Bus (USB) – USB standards, types and elements of USB transfers.

Parallel communications: General purpose interface bus (GPIB), GPIB signals and lines, handshaking and interface management, implementation of a GPIB on a PC; basic idea of sending data through a COM port. **Digital pulse modulation:** Need for digital transmission, pulse code modulation, digital carrier modulation techniques, sampling, quantization and encoding; concept of amplitude shift keying (ASK), frequency shift keying (FSK), phase shift keying (PSK), and binary phase shift keying (BPSK); comparison with analog pulse modulation.

(15 Lectures)

UNIT IV:
Architecture of Microprocessors: General definitions of mini computers, microprocessors, micro controllers and digital signal processors. Overview of 8085 microprocessor. Overview of 8086 microprocessor. Signals and pins of 8086 microprocessor. **Assembly language of 8086**: Description of Instructions. Assembly directives. Assembly software programs with algorithms. **Architecture of Micro controllers:** Overview of the architecture of 8051 microcontroller.

(15 Lectures)

References

1. Semiconductor Devices Physics and Technology, S M Sze, (Second Edition, 2002), John Wiley and Sons Inc. Asia.
2. Solid State Electronic Devices, Ben G Streetman, Sanjay Banerjee, (Fifth edition, 2000),
3. Pearson Education, Asia.
4. Semiconductor Optoelectronic Devices, Pallab Bhattacharya, (Second Edition, 1997), Pearson education, Asia.
5. Electronic Principles, A P Malvino, (Sixth Edition, 1999), Tata McGraw Hill, New Delhi.
6. Digital principles and applications, Donald P Leach and Albert Paul Malvino, (Fifth Edition, 2002), Tata McGraw Hill.

7. Digital systems, Principles and applications, Ronald J Tocci and Neal S Widmer, (Eighth Edition, 2001), Pearson Education.

8. PC Based Instrumentation: Concepts & Practice – N. Mathiavanan.

9. PC Based Instrumentation and Control – Mike Tooley

10. Microprocessor Architecture Programming & Applications – R.S. Gaonkar.

11. Microprocessor 8085: Architecture, Programming, & Interfacing – A. Wadhwa.

Course Title: Experimental Techniques			
Course Code	MSPHY1006E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Unit I

Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar, viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion).

Digital Instruments: Principle and working of digital meters, comparison of analog & digital instruments, characteristics of a digital meter.

(15 Lectures)

Unit II

Optical Microscopy; Scanning Electron Microscopy; Scanning Tunneling Microscopy; Atomic Force Microscopy; X-ray diffraction, Neutron diffraction

(15 Lectures)

Unit III

Transmission Electron Microscopy; Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction; Electron Spectroscopy for chemical analysis; Auger Electron spectroscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR, Raman and surface enhanced Raman Spectroscopy.

(15 Lectures)

Unit IV

X-ray Fluorescence; Rutherford back scattering; UV-VIS-NIR spectro-photometer, Ellipsometry; Deep Level Transient Spectroscopy; Thermally Simulated Current; C-V and Admittance Spectroscopy; Hall effect and Time of Flight methods for charge carriers, Differential scanning calorimeter; Differential Thermal Analyzer.

(15 Lectures)

Reference Books

1. Sayer, M., Mansingh, A., Measurement, Instrumentation and Experiment Design in Physics and Engineering, PHI (2000).

2. Nanotechnology-Molecularly Designed Materials : G.M. Chow & K.E. Gonsalves (American Chemical Society), 1996.

3. Nanoparticles and Nanostructured Films–Preparation, characterization and Application : J.H. Fendler (Wiley), 1998

Course Title: Biography of Indian Scientists			
Course Code	MSPHY1007E02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

Unit I

Historical Accounts of Ancient Indian Scientists: Baudhaayana, Aaryabhata, Brahmagupta, Bhaaskaraachaarya, Mahaaviiraachaarya, Kanaad, Varaahamihira, Naagaarjuna, Sushruta, Charak, Vaagbhatta, Patanjali, PaNini, Chaanakya; Pingala, Lagaadha, Bharata Muni, Madhvaachaarya, Dhanvantari, Kapila Muni, Bhaaradwaj Muni.

(15 Lectures)

Unit: II

Biographical Sketch of Modern Indian Scientists: Sir J C Bose, Prafulla Chandra Roy, Srinivas Ramanujan, Sir C Venkata Raman, Meghnad Saha, S N Bose, Shanti Swarup Bhatnagar, Homi Jehangir Bhabha, S Chandrashekhar, Vikram Sarabhai, C R Rao, K V Chandrashekhar, Har Govind Khurana, G N Ramachandra, Harish Chandra, M K Vainu Bappu, M Visvesvaraya, Subhash Mukhopadhyay, Raja Ramanna, A P J Abdul Kalam, Vashishtha Narayan Singh

(15 Lectures)

References

1. Biography of Indian Scientist - A Chattopadhyay
2. Bharat Ke Mahan Vaigyanik Famous Indian Scientists And Their Biographies - Arvind Gupta
3. The golden age of Indian mathematics - S Parameswaran; Swadeshi Science Movement Kerala
4. The history of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited
5. आचायरजगदीश चन बसु: १५०वी जयनी पर शदाञ्जिल – िनताई चन मणल (अनुवादक – डॉ. वीरेन कु मार िसंह)
6. भारत के प्रमुख गणिताचार्य– डॉ0 देवी प्रसाद वर्मा, श्रीराम चौथाईवाले, देवेन्द्रराव देशमुख; विद्या भारती संस्कृति शिक्षा संस्थान

Master of Science (M.Sc.) Physics Programme

Detailed Syllabus

(Effective from Academic Session 2020-2021)

SEMESTER - II

Course Title: Thermodynamics and Statistical Mechanics			
Course Code	MSPHY2001C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I: Thermodynamics
Postulates of equilibrium thermodynamics, Intensive and extensive variables, Thermodynamic definition of Entropy –Calculation of entropy changes in reversible processes, Equilibrium between two thermodynamic systems, Thermodynamic potentials –Enthalpy, Helmholtz and the Gibbs functions, The Maxwell relations, Variational principles in thermodynamics

(15 Lectures)

UNIT II: Classical statistical mechanics
Basic postulates of statistical mechanics, Macro-and micro states – Statistical equilibrium- Phase space, Ensemble: microcanonical, canonical, grand canonical; Density function- Liouville's theorem, Canonical distribution function: Evaluation of mean values in a canonical ensemble, Partition function--connection with thermodynamics; Statistical definition of entropy—Boltzmann equation and its significance; Ideal monoatomic gas, Gibbs' paradox, Equipartition theorem, specific heat of solids.

(15 Lectures)

UNIT III: Quantum statistical mechanics
Basic concepts – Quantum ideal gas, Identical particles and symmetry requirements, Quantum distribution functions, Bose-Einstein statistics, Ideal Bose gas, black body radiation, Bose- Einstein condensation, specific heat, Fermi-Dirac statistics, Ideal Fermi gas, properties of simple metals, Pauli paramagnetism, electronic specific heat, Quantum statistics in the classical limit.

(15 Lectures)

UNIT IV: Irreversible processes and fluctuations
Random walk in one dimension, Brownian motion, Langevin equation, Fluctuation dissipation theorem, Einstein relation, Fourier analysis of random functions, Wiener- Khintchine relations Nyquist's theorem, Fluctuations and Onsagar relations.

References

1. K. Huang, Statistical Mechanics, Wiley Eastern Limited, New Delhi, (1963).
2. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill, Singapore (1985).
3. R.K. Pathria, Statistical Mechanics, Bufferworgh Heinemann (2^{nd} Edition)
4. Silvio R A Salinas, Introduction to Statistical Physics, Springer, (2001)
5. B.B.Laud, Fundamentals of Statistical Mechanics, New Age International Publication(2003).

Course Title: Classical Electrodynamics and Relativity			
Course Code	MSPHY2002C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I: Electrostatics

Coulomb's law, Electric field, Gauss's law, applications of Gauss's law, Electric Potential, Poisson's equation and Laplace's equation, Work and energy in electrostatics, Techniques for calculating potentials: Laplace's equation in one, two and three dimensions, boundary conditions and uniqueness theorems, Method of Images, Multipole expansion Electrostatic fields in matter: Dielectrics, Polarization, Field inside a dielectric, Electric displacement, Linear dielectrics.

(9 Lectures)

UNIT II: Magnetostatics

Lorentz Force law, Biot-Savart Law, Divergence and Curl of B, Ampere's law and applications of Ampere's law, Magnetic vector potential, Multipole expansion. Magnetostatic fields in Matter: Magnetization, field of a magnetized object, magnetic field inside matter, linear and non linear magnetic media

(9 Lectures)

UNIT III: Electrodynamics

Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations. Scalar and vector potentials, gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics.

(9 Lectures)

UNIT IV: Electromagnetic waves

Electromagnetic waves in non conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reflection and transmission at interfaces. Fresnel's laws, interference, coherence transmission line and wave guides*;* Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion: Dispersion in non conductors, free electrons in conductors and plasmas. Guided waves.

(12 Lectures)

UNIT V: Electromagnetic Radiation

Retarded potentials, Electric dipole radiation, magnetic dipole radiation. Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion, Power radiated by a point charge.

(9 Lectures)

UNIT VI: Relativity

Electrodynamics and Relativity: Review of special theory of relativity, Lorentz transformations, Minkowski four vectors, energy-momentum four vector, covariant formulation of mechanics Transformation of electric and magnetic fields under Lorentz transformations, field tensor, invariants of electromagnetic field, Covariant formulation of electrodynamics, Lorentz force on a relativistic charged particle.

(12 Lectures)

References

1. Introduction to Electrodynamics – David J. Griffiths, Fourth Edition, Pearson, 2013.
2. Classical Electrodynamics – J.D. Jackson, Fourth Edition, John Wiley & Sons, 2005.
3. Classical Electromagnetic Radiation – M.A. Heald and J.B. Marion, Saunders, 1983.

Course Title: General Physics Lab – 1I			
Course Code	MSPHY2003C04	**Credits**	4
L + T + P	0 + 0 + 4	**Contact Hours**	120 (P)

List of Experiments:

1. To observe the dependence of the high frequency response of the analog link on D.C. Current passing through the photo transmitter.

2. To determine Bohr magneton and specific charge (e/m) of electron using Zeeman apparatus.

3. To determine Verdet's constant from the relation between rotation angle and magnetic flux using Faraday Effect apparatus.

4. To determine wavelength of laser using Michelson interferometer.

5. To study drain and transfer characteristics of JFET.

6. To study drain and transfer characteristics of MOSFET.

7. To study input, output and transfer characteristics of PNP / NPN transistor in CB mode.

8. To study input, output and transfer characteristics of PNP / NPN transistor in CE mode.

9. Application of IC- 555 as Pulse Generator Sequential Timer and pulse with modulator.

10. Construction and verification of half adder, full adder, half substractor, and full substractor using combinational circuits.

11. To construct and study JK, JKMS and T Flip flops.

12. Determination of ρ (rho) the resistance per unit length of a Carey Foster's bridge and find the melting point of given substance using Platinum resistance thermometer.

13. To study NAND gate as universal gate.

14. To study and verify binary storage counter, type t Flip – Flop, Up, Down and Decimal counter.

15. Construction and verification of Up / Down, synchronous/ asynchronous, ripple decade counters and 4 bits universal shift register.

16. Construction of Divide -by- N counters (6 or 60) using IC-7493 & IC-7490.

Course Title: Atomic and Molecular Physics			
Course Code	MSPHY2004C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

- ❖ Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

UNIT I

Atomic Structure and Atomic Spectra: One Electron Atom: Vector model of a one electron atom, Quantum states of an electron in an atom, Hydrogen atom spectrum, Spin-orbit coupling, Relativistic corrections for energy levels of hydrogen atom, Hydrogen fine structure, Spectroscopic terms, Hyperfine structure and isotopic shift.

(15 Hours)

UNIT II

Two valance Electron Atom: Vector model for two valance electrons atom, LS coupling, Pauli exclusion principle, Interaction energy for LS coupling, Lande interval rule, JJ coupling, interaction energy for JJ coupling. Inner shell vacancy, X-rays and Auger transitions. chemical shift. Frank-Condon principle. Atom in Magnetic Field: Zeeman effect, Magnetic moment of a bound electron, Magnetic interaction energy in weak field. Paschen-Back effect, Magnetic interaction energy in strong field.

(15 Hours)

UNIT III

Molecular Structure and Molecular Spectra :Types of molecules, Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Born-Oppenheimer approximation. Morse potential energy curve, Molecules as vibrating rotator, Vibration spectrum of diatomic molecule, PQR branches. Elementary discussion of Raman, ESR and NMR spectroscopy, chemical shift.

(15 Hours)

UNIT IV

Infrared spectroscopy: The vibrating diatomic molecule. The diatomic vibrating-rotator spectra of diatomic molecules Raman Spectroscopy: Introduction, Pure rotational Raman spectra, Vibrational Raman Spectra, Nuclear Spin and intensity alternation in Raman spectra, Isotope effect, Raman Spectrometer.

(15 Hours)

Text Books:

1. Concepts of Modern Physics by Arthur Beiser (McGraw-Hill Book Company, 1987).

Reference Books:

1. Atomic spectra & atomic structure, Gerhard Hertzberg: Dover publication, New York.
2. Molecular structure & spectroscopy, G. Aruldhas; Prentice – Hall of India, New Delhi.
3. Fundamentals of molecular spectroscopy, Colin N. Banwell & Elaine M. McCash, Tata McGraw –Hill publishing company limited.
4. Introduction to Atomic spectra by H.E. White,
5. Spectra of diatomic molecules by Gerhard Herzberg

Course Title: Elementary Solid State Physics			
Course Code	MSPHY2005C02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

Unit 1

Crystal structure: Periodic arrangement of atoms-lattice translation vectors, The basis and crystal structure, primitive and non-primitive lattice cell-fundamental types of lattice, -2D and 3-D Bravias lattice and crystal systems. Elements of symmetry operations points and space groups-nomenclature of crystal directions and crystal planes-miller indices, Bonding of solids, Defects and dislocations, Quasi crystals. Superfluidity. Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order **X-ray diffraction**: Scattering of x-rays, Laue conditions and Bragg's law, atomic scattering factor, geometrical structure factor, Reciprocal lattice and its properties.

(15 Lectures)

Unit 2

Properties of Solids: Elastic properties, phonons, lattice specific heat. Free electron theory and electronic specific heat. Response and relaxation phenomena. Drude model of electrical and thermal conductivity. Hall effect and thermoelectric power. Electron motion in a periodic potential, Introduction to band theory of solids: metals, insulators, Elementary ideas of quantum Hall effect, Cyclotron resonance and magnetoresistance, Introduction to superconductivity. Josephson junctions.

(15 Lectures)

<u>Reference Books:</u>

1. Solid State Physics- A. J. Dekker.
2. Solid State Physics- C. Kittel.
3. Elementary Solid state physics,- M.A. Omar.
4. Introduction of Solids: L.V. Azaroff.
5. Solid State Physics: N.W. Ashcroft and N.D. Mermin.
6. Crystallography Applied to Solid State Physics: A.R. Verma and O.N. Srivastava

Course Title: Elementary Nuclear & Particle Physics			
Course Code	MSPHY2006C02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

UNIT I

Static properties of nuclei : Rutherford scattering, Nuclear radius and charge distribution, nuclear form factor, Nuclear binding energy (review), Angular momentum, parity and symmetry, Magnetic dipole moment and electric quadrupole moment.

(6 Lectures)

UNIT II

Radioactive decays : Review of alpha decay, Beta decays, Gamma decay Fermi theory, Conservation laws, Allowed and forbidden transitions, Experimental evidence for parity-violation in beta decay, Electron capture probabilities, Double beta decay, Neutrino Detection of neutrinos, Internal conversion process, Production of nuclear orientation, Angular distribution of gamma rays from oriented nuclei. Nuclear reactions and mechanism, Compound nuclei and direct reactions.

(10 Lectures)

UNIT III

Nuclear Detectors : Interaction of radiation with matter (qualitative idea), Basics of Solid state detectors, Scintillation and gaseous detectors for particles and electromagnetic radiation detection. Idea of Calorimeter, Hybrid detectors and arrays.

(6 Lectures)

UNIT IV

Basic Concept of Particle Physics : Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction.

(8 Lectures)

References :

1. Nuclear and Particle Physics B. R. Martin, John Wiley & Sons Ltd
2. Nuclear Physics : Irving Kaplan (Narosa)
3. Basic Ideas and Concepts in Nuclear Physics : K. Hyde (Institute of Physics)

4. Introduction to Nuclear Physics ; Herald Enge (Addison-Wesley)

5. Nuclei and Particles : E. Segre (W.A. Benjamin Inc)

6. Introductory Nuclear Physics, Samuel S. M. Wong, Wiley-VCH Verlag GmbH & Co. KGaA

Course Title: Advanced Quantum Mechanics			
Course Code	MSPHY2007E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I: Scattering Theory
Kinematics of Scattering Process: differential and total cross-section -Asymptotic from of scattering wave function. Scattering amplitude by Green's method. Born approximation method and screened potential and square well potential as examples - Partial wave analysis and phase shift-Optical Theorem- Relationship between phase shift and Potential. Scattering by Hard sphere.

(12 Lectures)

UNIT II: Time Dependent Perturbation Theory
Time dependent perturbation theory - Constant and harmonic perturbations - Transition probabilities - Fermi's-Golden rule - Selection rules for dipole radiation - Adiabatic approximation - Sudden approximation - The density matrix - spin density matrix and magnetic resonance - Semi classical treatment of an atom with electromagnetic radiation.

(12 Lectures)

UNIT III: Many Electron Atom and Molecules
Thomas -Fermi atom – Self consistent method. Hartee – Fock method. Constants of motion in central field approximation-Corrections to the central field approximation. Born-Oppenheimer method-Molecular orbital theory. Valance bond theory. H2+ ion- Hydrogen molecule.

(12 Lectures)

UNIT-IV: Relativistic Quantum Mechanic
Klein –Gordon Equation, Plane wave solution and Equation of continuity, Probability density- Dirac Equation, alpha, beta- matrices, Plane wave solution, significance of negative energy states. Spin of Dirac particle Relativistic particle in central potential –Total Angular Moment, Particle in a magnetic field – Spin Magnetic moment, properties of gamma matrices- Dirac's equation in covariant form.

(12 Lectures)

UNIT V: Field Quantization
Lagrangian density and equation of motion for field, Symmetries and conservation laws, Noether's theorem, cononical quantization of scalar field, Complex scalar field, electromagnetic field and Dirac field, Problem in quanitizing electromagnetic field, Gupta & Bleuler method, Feynman rules (without derivation), Feynman diagrams.

(12 Lectures)

References:

1. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
2. Quantum Mechanics Concepts and Applications- Nouredine Zettile, Second Edison, John Wiley and Sons. 2009
3. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
4. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
5. Relativistic Quantum Mechanics: J.D. Bjorken and S.D. Drell.
6. Relativistic Quantum Fields: J.D. Bjorken and S.D. Drell.
7. A First Book on Quantum Field Theory: Amitabha Lahiri and P.B. Pal.
8. An Introduction to Quantum Field Theory: M. E. Peskin and V. Schroeder; Persues Book
9. Introduction to QFT: F. Mandle and G. Shaw
10. Advance Quantum Mechanics- J. J. Sakurai

Course Title: Advanced Mathematical Physics			
Course Code	MSPHY2008E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I:
Fourier and Laplace transforms: Fourier Series, Fourier transform, Convolution theorem, Parseval's theorem, Laplace transform and its properties, convolution theorem, inverse Laplace transforms, solution of differential equations using Laplace transforms, Fourier transform & Laplace transform of Dirac Delta function.

(30 Lectures)

UNIT II:
Complex analysis and Group theory: Functions of a complex variable, Analytic functions, Cauchy-Riemann relations, Cauchy's theorem, Cauchy's integral formula, Taylor and Laurent expansions, residue theorem, Evaluation of definite integrals, elementary idea of group theory.

(30 Lectures)

References

1. Mathematical methods of physics - J. Mathews and R. L. Walker, Second Edition, Addison-Wesley.
2. Mathematical methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012.
3. Complex functions – M. R. Spiegel, Schaum Series.
4. Mathematical Physics - P.K.Chattopadhyay, Wiley Eastern Ltd.1990.
5. Linear Algebra and Group theory for Physicists – K. N. Srinivasa Rao.

Course Title: Introduction of Ancient Indian Sciences			
Course Code	MSPHY2009E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Unit I

Basic Concepts: Some essential definitions; Classification of Indian Knowledge Systems; The objects of human pursuit; Fundamental basis for all Indian knowledge systems; The prescriptive nature of Indian discourses; The causal nature of universe; Means of acquiring knowledge; Prevalent social practice as source of knowledge - in view of modern statistical studies; Two way flow of knowledge; Vedas and Vedaangas; Evolution of Indian Science; Popularising Science among masses; Concept of cyclic time

(15 Lectures)

Unit II

Formal Structure of different Sciences:

Ancient Indian Mathematics: Definition of GaNita; Importance and all pervading nature of GaNita; Prescriptive nature of GaNita; Concept of zero; Decimal System; Arithmetics; Algebra;

Negative numbers; Trigonometry; GaNita in Vedaangas; Early Geometry; Concept π, $\sqrt{2}$, $\sqrt{3}$ etc.; Shulba-Sootra - Geometrical Calculations; GaNita Jyotisha; GaNita in prosody; GaNita in language; GaNita in music (Hemchandra Series); Binary system; Permutations and Combinations; Kerala school; Early Calculus; Upapatti - Indian version of proof; Similarities and contrast from modern mathematics

Ancient Indian Astronomy: Jyotisha - the science of time-keeping; Importance of Jyotisha; GaNita Jyotisha; Panchaanga; Phalita Jyotisha; Phalita Jyotisha and the causal nature of universe; works of different ancient scientists in the field of Jyotisha

Physics: Use of GaNita as prescription in contrast to use of mathematics as description; Motion; Gravitation; Concept of Paramaanu - Vaisheshik darshana; Syaatvaada and probabilistic interpretation of quantum mechanics; Cosmology; Causality; Physics in Jain and Bauddha darshana; Aprasiddha entities and its relevance in policy making of Indian science;

The science of Language: Meaning of Bhasha; Evolution of language; Praakrita and Sanskrita; Grammar of Sanskrita - Ashtadhyaayii by Paaninii; Sanskrit as world's most mathematical human language; Sanskrit for technical discourse; Basic knowledge of Sanskrita (Dhaatu, Pratyaya, Vibhakti, Vachana, Linga, Purusha; Lakaara, Sandhi, Samaasa); Order of words in Sanskrita; Rules to make new words; Falsification of word-to-word translation; Language as vehicle of culture and civilisation; Science in Sanskrita literature

The science of well-being: Definition of Ayurveda; Swaasthya in contrast to health; Importance of being healthy; Ayurveda as a way of life; Vaata, Pitta, Kapha; Quality of a good medicine; Yoga and Praanaayaama - definition and its importance as a method for well-being; Air, Water, Soil, Oil, Ghee, Cloth as a tool to heal; Mantra-healing; Surgery in ancient India; Healthy diet; Indian kitchen - a medicine store; Contribution of homemaking women in evolution of Ayurveda

Social and Economic Sciences: Expansion of self as family; Human body as a prototype of social structure; Family as a prototype for social administration; Gandhi's idea of Swaraajya; Sharing as a way of life; Economic system based on sharing; Sanskaaras - Prescription for proper distribution; Jaati as an economical unit; Village as an independent economic unit; Arthashaastra; Concept of virtual money in today's world and its absence in ancient Indian economic systems; Evolution of modern economic system based on virtual money, banks and markets; Comparative study of modern economic system with the ancient one; The Angus Maddison report

Other topics: Science of preservation of knowledge (Indian Education System); Comparative study of the oral and the scriptural traditions; Agricultural Sciences; Metallurgical Sciences; Computer Science; Civil Engineering; Architecture; Chemistry; Mechanical Engineering; Darshana in contrast to Philosophy; Indian systems as a solution to environmental problems; Role and π, 2, 3 status of women in Indian systems; Dharma in the root of all Indian sciences; Discussion on modern concept of patent/copyright in view of ancient practices

(45 Lectures)

References

1. Indian Science and Technology in the Eighteenth Century: Some Contemporary European Accounts - Dharampal; Other India Press

2. The History of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited

3. GaNita Yuktibhaasha: Rationales in mathematical astronomy of Jyeshthadeva (Volume I & II) - Malayalam text critically edited with English translation by K V Sharma (with explanatory notes by K Ramasubramanian, M D Srinivas & M S Sriram); Culture and History of Mathematics; Hindustan Book Agency

4. The golden age of Indian mathematics - S Parameswaran; Swadeshi Science Movement Kerala

5. पाचीन भारत मेिवजान एवं पौदोिगकी; िवजान भारती

6. Science in Samskrita; Samskrita Bharati

7. Pride of India: A glimpse into India’s scientific heritage; Samskrita Bharati

8. भारत मेिवजान की उजल परमरा - सुरेश सोनी

9. The Wonder that is Sanskrit - Sampad & Vijay; Auro Publications

10. गृहअथरशास; पुनरतान पकाशन सेवा टस

11. अथरशास - कौिटल

12. अषाङ्गहदयम् - वागट

13. चरक संिहता - चरक

14. सुशुत संिहता - सुशुत

Master of Science (M.Sc.) Physics Programme

Detailed Syllabus

(Effective from Academic Session 2020-2021)

SEMESTER - III

Specialization

Condensed Matter Physics

Course Title: Condensed Matter Physics			
Course Code	MSPHY3001C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Unit-1
Ewald's method, Lorentz field, Phonons in perfect-crystals: General theory of lattice dynamics of non-primitive lattice, normal coordinate description, quantization of lattice vibrations, phonon concept, ionic crystals, shell model. Inelastic scattering of slow neutrons by crystals for study of phonons. Kramer-Kronig relation.

(15 Lectures)

Unit-2
Dielectric constant of ionic crystals. Static polarizability, polarizability in variable field, placzek's approximation, first order Raman scattering, second-order Raman scattering, elementary ideas of the study of phonons by Raman scattering Plasmons, interaction of electromagnetic waves with phonons and polaritons.

(15 Lectures)

Unit-3
Excitation in imperfect crystals: Definition of classical Green functions, application to one dimensional harmonic oscillator, principle of causality. Double-time quantum Green functions, correlation functions, and spectral density. Static Green function (Fourier transform), application to lattice vibrations and Electron energy states. Point defect in one dimensional lattice, localized, gap and resonance modes. Elementary ideas of extension to impurity electron energy states, gap states.

(15 Lectures)

Unit-4
Transport Theory: Phenomenological coefficient Lij and their physical interaction. General Boltzmann equation and its linearization Entropy production. Relaxation time solution of Boltzmann equation. Electronic contributions of thermal and electrical conductivities and to Peltier, Seeback coefficient for metals and electronis semiconductors. Relationship between electrical and ideas about lattice contribution to thermal conductivity.

(15 Lectures)

<u>Reference Books:</u>

1. Solid State Physics- A. J. Dekker.
2. Solid State Physics- C. Kittel.
3. B.E.Warren – X-ray Diffraction.
4. A. Maradudin – Solid State Physics (Supplement 3) (Academic Press).
5. O. Madelung – Introduction of Solid State Theory (Springer).
6. J.M. Ziman: Principles of the theory of solids

Course Title: Solid State Devices			
Course Code	MSPHY3002C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Unit- I:

Classification of Semiconductors; Crystal structure with examples of Si, Ge & GaAs semiconductors; Energy band structure of Si, Ge & GaAs; Extrinsic and compensated Semiconductors; Temperature dependence of Fermi- energy and carrier concentration. Drift, diffusion and injection of carriers; Carrier generation and recombination processes- Direct recombination, Indirect recombination, Surface recombination, Auger recombination; Applications of continuity equation- Steady state injection from one side, Minority carriers at surface, Haynes Shockley experiment, High field effects. Hall effect; Four – point probe resistivity measurement; Carrier life time measurement by light pulse technique. Introduction to amorphous semiconductors, Growth of semiconductor crystals.

(18 Lectures)

Unit- II:

Fabrication of p- n junction by diffusion and ion- implantation; Abrupt and linearly graded junctions; Thermal equilibrium conditions; Depletion regions; Depletion capacitance, Capacitance – voltage (C- V) characteristics, Evaluation of impurity distribution, Varactor; Ideal and Practical Current-voltage (I- V) characteristics; Tunneling and avalanche reverse junction break down mechanisms; Minority carrier storage, diffusion capacitance, transient behavior; Ideality factor and carrier concentration measurements; Carrier life time measurement by reverse recovery of junction diode; p- i- n diode; Tunnel diode, Introduction to p- n junction solar cell and semiconductor laser diode.

(18 Lectures)

Unit- III:

Schottky barrier – Energy band relation, Capacitance- voltage (C- V) characteristics, Current- voltage (I- V) characteristics; Ideality factor, Barrier height and carrier concentration measurements; Ohmic contacts. Bipolar Junction Transistor (BJT): Static Characteristics; Frequency Response and Switching. Semiconductor heterojunctions, Heterojunction bipolar transistors

(10 Lectures)

Unit- IV:

Junction Field Effect Transistor (JFET) - Construction, Characteristic parameters, Transfer Characteristics, applications; Introduction to ideal MOS device; MOSFET fundamentals, Measurement of mobility, channel conductance etc. from I_{ds} vs V_{ds} and I_{ds} vs V_g characteristics; Metal- semiconductor field effect transistor (MESFET)- Device structure, Principles of operation, Current voltage (I- V) characteristics, High frequency performance.

(14 Lectures)

References:

1. S.M. Sze; Semiconductor Devices: Physics and Technology, 2nd edition, John Wiley, New York, 2002.
2. B.G. Streetman and S. Benerjee; Solid State Electronic Devices, 5th edition, Prentice Hall of India, NJ, 2000.
3. W.R. Runyan; Semiconductor Measurements and Instrumentation, McGraw Hill, Tokyo, 1975.
4. Adir Bar- Lev: Semiconductors and Electronic devices, 2nd edition, Prentice Hall, 1984.
5. Donald A. Neamen; Semiconductor Physics and Devices: Basic Principles, 3rd edition, Tata McGraw- Hill, New Delhi, 2002.
6. M. Shur; Physics of Semiconductor Devices, Prentice Hall of India, New Delhi, 1995.

Course Title: Solid State Physics Lab – 1			
Course Code	MSPHY3003C04	**Credits**	4
L + T + P	0 + 0 + 4	**Contact Hours**	120 (P)

❖ **List of Instruments:**

1. To study the relationship between temperature of given samples (1&2) and its time of cooling by plotting a cooling curve and identify the samples.
2. To study Hall Effect in semiconductor and determine Hall coefficient (Rh) &charge career density.
3. Characterization of Nano-fluids like Ag/Au & ferrofluids.
4. To evaluate modest nano-particles concentrations in the fluid for significant enhancement of its property.
5. Study of phase transition and to detect/assess weak and strong molecular interactions in nano-fluids.
6. To determine the Stefan's constant by using an incandescent lamp and Photovoltaic cell.
7. To demonstrate Hysteresis curve of hard magnet.
8. To determine Dielectric constant of specimen at high frequency by Lecher wires.
9. To study the dispersion relation for mono-atomic lattice and determine the cut of frequency.
10. To determine heat capacity of solids
11. Measurement of Planck's constant using LED.
12. Measurement of Planck's constant using photo voltaic cell.

❖ Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Materials Science			
Course Code	MSPHY3004E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Unit-I

Formation and structure of materials: Introduction to Materials Science- Engineering materials - structure - property relationship, Review of ionic, covalent and molecular bindings, bond angle, bond length and bond energy, lattice energy - Madelung constant cohesive energy, van der Waal's Interaction- Lennard- Jones Potential, closed packed structure-packing efficiency and density of materials. Crystal imperfections: Review of crystalline imperfection, Schottky and Frenkel defects- Equilibrium concentrations, edge and screw dislocations, surface imperfections.

(15 Lectures)

Unit -II

Elastics and plastics behavior of materials:

Atomic model of elastic behavior-rubber like Elasticity- anelastic behavior, viscoelastic behavior, fracture of materials-Ductile and brittle fracture – Ductile brittle transition, protection against fracture Plastic deformation by slip-shear strength of perfect and real crystals- CRSS ratio, maximum stress to move dislocation, methods of strengthening crystalline materials against plastic deformation-strain hardening, grain refinement, solid solution strengthening, precipitation strengthening.

(15 Lectures)

Unit- III

Composite materials: Classification of composite materials, matrix materials- polymer, metals, ceramics, reinforcing materials- fibers, particles, concrete-concrete making materials, structure, composition, properties and applications, polymer-concrete composites, fabrication, structure, application of polymer matrix composites, metal matrix composites, ceramic-matrix composites, carbon-fibre composites, fibre reinforce, particle reinforce composites with properties and applications.

(15 Lectures)

Unit -IV

Elements of polymer science: Monomers- Polymers- classification polymers, synthesis of polymers-chain polymerization, step polymerization, Industrial polymerization methods, Average molecular weight-weight, number & viscosity, size of polymer molecule. Microstructure of polymers- chemical, geometric, random, alternating and block polymers. Phase transition-Polymer melting and glass transition, stereo isomerism, degree of crystallinity. Process of plastic materials: Moulding- compression, injection, blow, extrusion, spinning.

(15 Lectures)

Reference Books

1. Elements of Materials Science and Engineering: Lowrence H. Van Vlack, Addison

2. Wesley, (1975).
3. Introduction to Ceramics: W D Kingery, H K Bower and VR`uhlman, John Wiley, (1960)
4. Foundations of Materials Science and Engineering-William F. Smith, McGraw Hills International Edition, (1986)
5. Materials Science and Engineering, V. Ragharan, Prentice Hall (1993)
6. Structure & Properties of materials-vol I-IV Rose, Shepard and Wulff (1987)
7. Polymer Science, V. R Gowariker, N.V. Vishwanathan, Joydev Shreedhar, Wiley Eastern(1987)
8. Text of Polymer Science, Fred. W.Billmeyer, John Wiley and Sons, Inc. (1984)
9. Materials Science and Engineering W.D. Callister Wiley

Course Title: Crystal Growth and Characterization			
Course Code	MSPHY3005E04	**Credits**	4
L + T + P	2 + 0 + 2	**Contact Hours**	30 (L) 60(P) Hours

Unit – I: Fundamentals of Crystal Growth

Importance of crystal growth – Classification of crystal growth methods – Basic steps: Generation, transport and adsorption of growth reactants – Nucleation: Kinds of nucleation –Classical theory of nucleation: Gibbs Thomson equations for vapour and solution – Kinetic theory of nucleation – Becker and Doring concept on nucleation rate – Energy of formation of a spherical nucleus – Statistical theory on nucleation: Equilibrium concentration of critical nuclei, Free energy of formation.

(10 Lectures)

Unit – II: Crystal Growth Techniques

Melt Growth : Basics of melt growth – Heat and mass transfer – Conservative growth processes: Bridgman-Stockbarger method – Czochralski pulling method – Kyropolous method – Nonconservative processes: Zone-refining – Vertical and horizontal float zone methods – Skull melting method – Vernueil flame fusion method.

Solution Growth : Growth from low temperature solutions: Selection of solvents and solubility – Meir's solubility diagram – Saturation and supersaturation – Metastable zone width – Growth by restricted evaporation of solvent, slow cooling of solution and temperature gradient methods– Crystal growth in Gel media: Chemical reaction and solubility reduction methods – Growth from high temperature solutions: Flux growth Principles of flux method – Choice of flux – Growth by slow evaporation and slow cooling methods.

Vapour Growth : Basic principles – Physical Vapour Doposition (PVD): Vapour phase crystallization in a

closed system – Gas flow crystallization – Chemical Vapour Deposition (CVD): Advantageous and disadvantageous

(20 Lectures)

Practical :- Growth and Characterization

- Growth of crystals
- Characterization and analysis using
  - Single crystal X-Ray Diffraction
  - Powder X-Ray Diffraction,
  - FT-IR spectroscopy,
  - UV-Vis spectroscopy,
  - Raman Spectroscopy,
  - Dielectric, Non Linear
  - Optical (NLO) Studies

(60 Practical Hours)

References:

1. J.C. Brice, Crystal Growth Processes, John Wiley and Sons, New York, 1986,
2. J.W. Mullin, Crystallization, , Elsevier Butterworth-Heinemann, London, 2004

Course Title: Crystallography, Crystal Structures and Diffraction Techniques			
Course Code	MSPHY3006E04	**Credits**	4
L + T + P	2 + 1 + 1	**Contact Hours**	30 (L)++15(T)+30(P) Hours

3. Ichiro Sunagawa, Crystals: Growth, Morphology and Perfection, Cambridge University Press, Cambridge, 2005.
4. B.R. Pamplin, Crystal Growth, Pergamon Press, Oxford, 1975
5. Characterization of Materials (Materials Science and Technology:A Comprehensive treatment,Vol 2A & 2B, VCH (1992).
6. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press (2008).
7. P.E. J. Flewitt and R K WildPhysical methods for Materials Characterization, , IOP Publishing (2003).

Unit-I

Close packing of spheres. Structure of common metals, alloys, ionic, covalent and molecular crystals, Production and properties of x-rays: Continuous and characteristic spectrum. Interaction of X-rays with matter. Laue equations. Bragg's law. Reciprocal lattice concept and its applications to rotation, Laue and Debye Scherrer techniques. Powder diffractometry. Space group symmetries.

(15 Lectures)

Unit –II

General procedure for working out the details of space groups with illustrations from triclinic, monoclinic and orthorhombic systems. Wyckoff positions. Principles of crystal structure analysis. Structure factor calculations. Space group extinctions. Electron density functions. Phase problem. Patterson functions. Direct methods in crystallography. Debye Scherrer, Guinier and Bragg-Brentano geometries for powder diffractometers. General intensity expression for powder diffraction. Rietveld refinement technique. Quantitative phase analysis and microstructure determination. Limitations of powder method. Single crystal diffractometers. Indexing of electron diffraction patterns

(15 Lectures)

List of Experiments

1. Phase problem and determination of crystal structures.
2. Indexing of X-Ray powder diffraction patterns.
3. Atomic scattering factor and structure factor determination.

4. Experimental determination of space group and inversion symmetry.
5. Structure Refinement procedures

Reference Books

1. X-ray Diffraction B.D. Culty
2. Crystallography Verma and Srivastava
3. B.E.Warren – X-ray Diffraction.
4. Maradudin – Solid State Physics (Supplement 3) (Academic Press).
5. O. Madelung – Introduction of Solid State Theory (Springer).
6. J.M. Ziman: Principles of the theory of solids

Course Title: Fundamental of Nanoscience and Nanotechnology			
Course Code	MSPHY3007E04	**Credits**	4
L + T + P	4	**Contact Hours**	60 (L) Hours

Unit I:

Metal nanoclusters: Magic numbers, Geometric Structure, Electronic Structure, Bulk- to- Nano transition;

Semiconducting nanoparticles: Optical properties; Rare- gas and molecular clusters: Inert gas clusters, Superfluid clusters, Molecular clusters, **Methods of synthesis:** RF plasma, Chemical methods, Thermolysis, Pulsed- Laser method **Cohesive Energy:** Ionic solids, Defects in Ionic solids, Covalently bonded solids, Organic crystals, Inert- gas solids, Metals **Quantum wells, wires and dots:** Fabricating techniques for Quantum Nanostructures, effect of size and dimension on conduction electrons, Applications

(15 Lectures)

Unit II:

Vibrational Properties: The finite One- dimensional monoatomic lattice, Ionic solids, Experimental Observations: Optical and acoustical modes; Vibrational spectroscopy of surface layers of nanoparticles – Raman spectroscopy of surface layers, Infrared Spectroscopy of surface layers; Photon confinement, Effect of dimension on lattice vibrations, Effect of dimension on vibrational density of states, effect of size on Debye frequency, Melting temperature, Specific heat, Phase transitions.

Electronic Properties: Effect of lattice parameter on electronic structure, Free electron model, The Tight- Binding model; Measurements of electronic structure of nanoparticles: Semiconducting nanoparticles, Organic solids, Metals.

(15 Lectures)

Unit III:

Mechanical Properties: Stress- Strain Behavior of materials; Failure Mechanism of Conventional Grain-Sized Materials; Mechanical Properties of Consolidated Nano- Grained Materials; Nanostructured Multilayers; Mechanical and Dynamical Properties of Nanosized Devices, Methods of Fabrication of Nanosized Devices.

(15 Lectures)

Unit IV:

Magnetism in Nanostructures : Basics of Ferromagnetism; Behavior of Powders of Ferromagnetic Nanoparticles : Properties of a single Ferromagnetic Nanoparticles, Effect of nanosized grain structure on magnetic properties, Magnetoresisitive materials;

Spintronics: Definition and examples of spintronic devices, Magnetic storage and spin valves, Dilute magnetic semiconductors; Molecular switches and electronics: Molecular switches, Molecular electronics, Mechanism of conduction through a molecule; Photonic crystals.

(15 Lectures)

References:

1. The Physics and Chemistry of Nanosolids, Frank J. Owens and Charles P. Poole, Wiley-Interscience, 2008.

2. Frank J. Owens, Physics of Magnetic Nanostructures, Wiley- Interscience, 2015.

Course Title: Physics of Dielectric and Ferroelectric Materials			
Course Code	MSPHY3008E02	**Credits**	2
L + T + P	2+0+0	**Contact Hours**	30 (L) Hours

Unit I:

Introduction to Dielectrics: Polarisation mechanisms in dielectrics: induced, orientational, electronic, ionic, interfacial and lattice polarizations; combined mechanisms. Classical and quantum theory of polarization, Dielectric Relaxation mechanism, Applications of dielectrics

Macroscopic electric field – Local electric field at an atom – Dielectric constant and polarizability – Clausius-Mossotti equation, The complex impedance method, calculations of permittivity and dielectric losses, cole-cole plots.

Spontaneous polarization and ferroelectrics, Phase Transitions of the first and second order. Ferroelectric Liquid Crystals. Fundamental of piezoelectricity, Search method for ferroelectric and piezoelectric materials, Material processing for ferroelectric and piezoelectric materials, Characterization technique of piezoelectricity, Defect studies of ferroelectric and piezoelectric materials, Application of ferroelectric and piezoelectric materials.

(20 Lectures)

Unit II

Case Studies:

- Study of the ferroelectric properties of thin films by using sawyer tower circuit
- Study of dielectric relaxation phenomena,
- Study of the temperature dependence of permittivity in ferroelectrics
- Study of the RLC circuit with nonlinear capacitor,
- Determination of field-dependence of permittivity in ferroelectrics,
- Study of the piezoelectric effect by the method of resonance impedance.

(10 Lectures)

References:

1. Gerald Burns, Solid State Physics, Academic Press, 1990.

2. Kwan Chi Kao, Dielectric Phenomena in Solids, Elsevier Academic Press (2004)
3. J.D. Livingston, Electronic Properties of Engineering Materials, Wiley, 1999
4. L.L. Hench and J.K. West, Principles of Electronic Ceramics, Wiley, 1990
5. J. Grindlay, An introduction to the phenomenological theory of ferroelectricity, Pergamon Press, Oxford, 1970
6. Karin M. Rabe, Charles H. Ahn, Jean-Marc TrisconePhysics of Ferroelectrics: A Modern Perspective, Springer (2007)

Course Title: X-Ray Spectroscopy			
Course Code	MSPHY3009E02	**Credits**	2
L + T + P	2+0+0	**Contact Hours**	30 (L) Hours

UNIT I

Source of X-rays (classic and synchrotron radiation), Interaction of x-rays with matter (photoeffect, Compton effect, elastic scattering, Auger effect), Detectors for X-rays, Optical elements for X-rays (mirrors, monochromators, (micro)focusing elements) , X-ray diffraction, small angle scattering, X-ray fluorescence, X-ray absorption spectroscopy, Introduction to analysis of atomic and molecular structure with x-ray spectroscopic methods; Micro-spectroscopy (combination of XAS and micro focusing of SR X-ray beam) and 2D elemental mapping with sub-micron resolution, In-situ in in-operando spectroscopic techniques with X-rays

(20 Lectures)

UNIT II

Photoemission Electron Microscopy - X-ray Absorption Spectroscopy - X-ray Magnetic Linear Dichroism (XMLD) - X-ray Magnetic Circular Dichroism (XMCD) - Temperature and angle dependence of X-ray Magnetic Dichroism.

(20 Lectures)

References:

1. G. Bunker, "Introduction to XAFS: A Practical Guide to X-ray Absorption Fine Structure Spectroscopy", Cambridge University Press, 2010
2. X-ray absorption spectroscopy (principles, applications, techniques of EXAFS, SEXAFS and XANES), edited by D.C. Konnigsberger and R. Prins, John Wiley and Sons, NY (1988)
3. D. A. Skoog, F. J. Holler, T. A. Nieman, Principles of Instrumental analysis, Saunders Colege Publishing, Philadelpia, 1998

Course Title: Diffusion in Solids			
Course Code	MSPHY3010E02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

Unit 1

Laws of diffusion. Solution of Fick's diffusion equation under simple boundary conditions. Types of diffusion. Diffusion and concentration gradient. Compositional dependence of diffusion. Diffusion in metals and alloys.

(15 Lectures)

Unit II

Methods of determining diffusion coefficients. Diffusion in ionic solids. Diffusion and conductivity. Point defects. Interaction of point defects. Analysis of typical binary compounds. Diffusion in ternary compounds, ferrites, oxides, sulfides, silicates etc. Diffusion and solid state reactions.

(15 Lectures)

Reference Books:

1. Elements of Materials Science and Engineering: Lowrence H. Van Vlack, Addison
2. Wesley, (1975).
3. Introduction to Ceramics: W D Kingery, H K Bower and VR`uhlman, John Wiley, (1960)
4. Foundations of Materials Science and Engineering-William F. Smith, McGraw Hills
5. International Edition, (1986)
6. Materials Science and Engineering, V. Ragharan, Prentice Hall (1993)
7. Structure & Properties of materials-vol I-IV Rose, Shepard and Wulff (1987)
8. Materials Science and Engineering W.D. Callister Wiley

Course Title: Fundamentals of Scanning Probe Microscopy			
Course Code	MSPHY3011E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Unit I: Tip-Surface Interaction
Non-contact regime Intra-molecular Interactions, Electric Dipoles, Inter-molecular interactions: Physical models, ion-dipoles, Keesom forces, Dispersion Force, ***Contact regime*** Hamaker theory, surface energies, Dejaugin approximation, contact mechanics, Hertz model, JKR model, DMT model

(12 Lectures)

Unit II: Atomic Force Microscope (AFM)
AFM components, AFM calibration, Contact Mode Scans
Force Spectroscopy Cantilever mechanics, Approach-retract curves, Processing Force curves, Modulus and adhesion Maps, Lateral Force Microscopy, Conducting Atomic Force Microscopy, Nano-indentation

(12 Lectures)

Unit III: Dynamic AFM methods
Point Mass Model of Dynamic AFM, frequency response, conservative and dissipative interaction forces, interacting with the surface, ***Analytical theory of Dynamic AFM*** : Excited probe interacting with sample (linear theory), Amplitude and Frequency modulation AFM, Non-linear/dissipative interactions, Attractive and Repulsive Regimes and Phase Contrast Modualtion AFM, ***Reconstructing Surface Forces*** Relationship between Frequency shift and Potential Energy, reconstruction of interaction force from frequency shift in FM-AFM, Experimental details of FM-AFM measurements

(12 Lectures)

Unit IV: Dynamic AFM for Electrostatics/Magnetic/Biology
Measuring Electrostatic Forces, Measuring Magnetic Forces, Dynamic AFM in Liquids, Specialized dynamic-AFM based techniques for physical property measurements: Piezo-response force microscopy, Scanning non-linear dielectric microscopy, Magnetic exchange force microscopy

(12 Lectures)

Unit-V: Scanning Tunneling Microscopy
Quantum tunneling, WKB approximation for field emission, STM instruments and its components, Scanning tunneling spectroscopy, Inelastic electron tunneling spectroscopy; Atomic/molecular manipulations, spin-polarized STM, radio-frequency STM

(12 Lectures)

References:

1. Scanning Probe Microscopy and Spectroscopy: Methods and Applications, Roland Wiesendanger, Cambridge University Press, 1994
2. Fundamentals of Scanning Probe Microscopy, V. L. Mironov, The Russian Academy of Sciences, Institute for Physics of Microstructures, 2004
3. Scanning Probe Microscopy: Electrical and Electromechanical Phenomena at the Nanoscale, Sergei V. Kalinin, Alex Gruverman, Springer-Verlag New York, 2007
4. Scanning Probe Microscopy: Atomic Force Microscopy an Springer-Verlag Berlin Heidelberg, 2015.
5. Springer Handbook of Nanotechnology, Ed. Bharat Bhushan, Springer-Verlag Berlin Heidelberg, 2010

Master of Science (M.Sc.) Physics Programme

Detailed Syllabus

(Effective from Academic Session 2020-2021)

SEMESTER - IV

Specialization

Condensed Matter Physics

Course Title: Advanced Condensed Matter Physics			
Course Code	MSPHY4001C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT: I

Magnetism: Classical and Semi Classical Theories : Failure to explain large internal fields. Exchange interaction. Ising Model. Bragg William Approximation. Explanation of large external fields. Non-existence of ferromagnetism in two-dimensional Ising Model. Two sublattice Model and classical theories of antiferromagnetic and ferrimagnetism, Ferrites and garnets.

(15 Lectures)

UNIT: II

Second Quantized Theory: Ferromagnetic Heisenberg Hamiltonian, Holstein Primak off transformations and their application to Heisenberg Hamiltonian for small fractional spin reversal. Ferromagnetic magnons, Magnon heat capacity and saturation magnetization at small temperatures. Antiferromagnetic Hamiltonian and its reduction using Holstein Primak off transformation, Antiferromagnetic magnons. Zero point sub-lattice magnetization. The Magnetic Phase Transition :Order parameter, Landau's theory of second order phase Transitions. Fluctuations of the order parameter. Elementary qualitative ideas about critical exponents and scaling.

(15 Lectures)

UNIT: III

Many Electron Systems: Second quantization for Fermions, field operators, electron density operator, Hamiltonian for two particle interactions in second quantized form: Columbian interaction and screened Colombian interaction. Linear Response Theory: Dielectric response analysis, dielectric constant for electron gas in self-consistent approximation, Lindhard formula, dielectric constant. Dielectric screening of a point charge impurity.

(15 Lectures)

UNIT: **IV**

Electron-Phonon Interaction: Long wavelength limit, deformation potential interaction, Born approximation, deformation potential perturbation Hamiltonian, Normal processes, polaron. Number of phonons accompanying electron. Electron-electron interaction via phonons, Attractive interaction, Cooper pairs, Reduced Hamitonian for superconducting state. Bogoliubo-Valatin tranformation, Diagonal and non-diagonal terms, superconducting ground state energy, nature of ground state, excited states, Temperature dependence of energy gap, Transition temperature, Simple treatment of Meissner effect and flux quantization.

(15 Lectures)

Reference Books:

1. Solid State Physics- A. J. Dekker.
2. Solid State Physics- C. Kittel.
3. Introduction of Solids: L.V. Azaroff.

4. olid State Physics: N.W. Ashcroft and N.D. Mermin.
5. Solid State Physics: Mattis
6. Electron Paramagnetic Resonance: Pake
7. Molecular spectroscopy: Banwell.

Course Title: Solid State Physics Lab – 1I			
Course Code	MSPHY4003C04	**Credits**	4
L + T + P	0 + 0 + 4	**Contact Hours**	120 (P)

❖ **List of Experiments:**

1. To study characteristics of a solar cell.
2. To measure the charge Q on a plate capacitor as a function of the applied voltage E.
3. To determine the capacitance C as a function of areas A of plates.
4. To determine the capacitance C with different dielectrics between the plates.
5. To determine the capacitance C as a function of the distances d between the plates.
6. To determine resistivity of a given semiconductor by Four probe.
7. To draw the characteristics of a P-N junction diode for reverse saturation current and temperature.
8. To determine the Band gap in a semiconductor using a junction diode.
9. To study Hall effect in semiconductor and determine Hall coefficient (Rh), mobility ,Hall angle tan (θ) & conductivity .
10. Crystallographic measurements using XRD.

❖ Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Physics of Magnetism & Spintronics			
Course Code	MSPHY4004E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I:

Magnetism in metals: Free electron model, Pauli paramagnetic, Spontaneously spin-split bands, Landau levels, Landau diamagnetism, Magnetism of the electron gas, Excitations in the electron gas, Spin density waves, Kondo effect, The Hubbard model.
Magnetic anisotropy: Shape anisotropy, Magneto-crystalline anisotropy and its origin, Induced anisotropy Competing interactions and low dimensionality: Magnetic frustration, Spin glasses, Superparamagnetic, One and two-dimensional magnets, Spin chain, Spin-Peierl's transition, Spin ladders

(15 Lectures)

UNIT II

Introduction- overview of development of Spintronics and its future scope, Magnetic multilayers, Magnetic Anisotropy of thin films, Interlayer Exchange Coupling and Exchange Bias, Spin dependent transport - Anisotropic magnetoresistance, Giant Magneto Resistance (GMR) effect - Phenomenological theory, Microscopic theory for current in plane (CIP) and current perpendicular to plane (CPP) GMR, Effects of spin-flip scattering Spin tunneling, Tunnel Magnetoresistance (TMR), Effects of Fermi surface, Effect of interfacial states, diffusive tunneling, Spin flip tunneling, Bias voltage dependence of TMR, Magnetic tunnel Junctions (MTJ), Tunnel Junctions with Half Metals

(15 Lectures)

UNIT III

Introduction to thin films, Technology as a drive and vice versa, Basics of vacuum science and technology, Vacuum pumps and gauges. Physical vapor deposition, Raoult's law of evaporation, evaporation rate, evaporation of elements, compounds and alloys, Hertz Knudsen equation; Knudsen cell, Film Thickness Uniformity and Purity

(15 Lectures)

UNIT IV

Molecular beam epitaxy (effusion cell, growth rate, growth of GaAs/AlGAs and GSMBE), Role of Kinetics of Adsorption and Desorption, Surface reconstruction, In-situ film characterization of MBE films by LEED and RHEED, & RHEED Oscillations, Pulsed Laser deposition (PLD process steps, congruent evaporation, advantages and disadvantages of PLD). CVD advantages, CVD Reaction types, Thermodynamics of CVD, Gas Transport, Viscous flow, Close-Spaced Vapor Transport (CSVT), Convection, Film Growth Kinetics, Axial and radial film thickness uniformity, Classification of CVD systems, APCVD, LPCVD & MOCVD and Examples of CVD growth.

(15 Lectures)

References

1. S. Blundell, Magnetism in Condensed Matter, 1st edition, Oxford University Press, 2001.
2. R. C. O' Handley, Modern Magnetic Materials, John Wiley & Sons, Inc., 2000.
3. T. Shinjo (Ed.) Nanomagnetism and Spintronics, 1st edition, Elsevier, 2009.
4. E. Y. Tsymbal and I Zutic, Handbook of Spin Transport and Magnetism, CRC Press, 2012.
5. Materials Science of Thin Films Deposition and Structure, Milton Ohring.
6. Thin Film Solar Cells, Chopra and Das
7. Thin Film Deposition: Principles and Practice, Donald Smith.
8. Handbook of Thin Film Deposition (Materials and Processing Technology), Krishna Seshan.
9. Handbook of Physical Vapor Deposition, D. M. Mattox.

Course Title: Alloy Design and Development			
Course Code	MSPHY4005E04	**Credits**	4
L + T + P	2 + 0 + 2	**Contact Hours**	30 (L) + 60(P) Hours

Unit-I

Concept and of alloy design, Steps in alloy design, Significance of alloy design. Single phase, dual phase and multiphase materials, Effect of size, shape and distribution of second phase on mechanical and magnetic properties of alloys. Precipitation and particle coarsening, re-crystallization and grain growth. Solid/Liquid phase transformation in pure metals, single phase alloys, constitutional super cooling and eutectic alloys.

(15 Lectures)

Unit-II

Standards in alloy steels – Study of a few selected standards. Quasicrystalline alloys, Alloy steel design for better tensile strength, ductility, toughness, fatigue strength, creep strength, wear resistance and elevated temperature strength. Alloy design of lightweight, high strength, corrosion resistance Non Ferrous alloys, Magnetic alloys, Multicomponent alloys and their Applications. Different synthesis routes and their effect on properties of Alloys.

(15 Lectures)

List of Experiments

- Synthesis of alloys through different synthesis routes e.g. mechanical alloying, solid state synthesis, arc melting, and induction melting.
- Effect annealing temperature on phase revolution and properties of different alloys.
- Effect annealing condition on phase revolution and properties of different alloys.
- Mechanical, Magnetic and corrosion behaviors of different alloys.
- Development of important Alloys.

Reference Books

1. ASM Handbook, Vol.1 & 2, Properties and Selection: Metals Park, Ohio.
2. Boyer, H.E.(ed.), Selection of Materials for component Design: Source Book, American Society for Metals, Metals Park, Ohio
3. Ashby, M.F. Materials Selection in Mechanical Design, New York: Pergamon, 1992.
4. Ranganathan S., Arunachalam V.S. and Cahn R.W. (Eds.), Alloy Design, Indian Academy of Science, Bangalore,1981.
5. Tien John K. and Ansell George S. (Eds.), Alloy and Micro structural Design, Academic Press.
6. Structure & Properties of Alloys – Robert M. Brick, Robet B. Gordon & Arthur Phillips, Eurasia Publishing House (private) Ltd., New Delhi
7. Metals Hand Book Ninth Edition – Vol 1

Course Title: Materials Synthesis and Processing			
Course Code	MSPHY4006E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Unit I

Introduction: Materials processing science with special emphasis on processing of polymers and ceramics and metals

(2 Lectures)

Unit II

Polymer processing: Rheology of polymeric materials, Compounding of plastics, processing techniques: Compression, Transfer, injection, blow molding, Extrusion, Calendaring, Thermoforming, Rotational molding, Compounding and processing of rubber (both latex and dry rubber) with different formulations: Casting, rubber extrusion, Dip coating (gloves, balloons etc.), fibre spinning and manufacturing processes.

(12 Lectures)

Unit III

Ceramic processing: Processing of traditional ceramics- spray granulation, Pressing, Slurry processing, Slip casting, Pressure casting, Tape casting, Gel casting, Injection molding, Extrusion; Rapid prototyping through Additive manufacturing, Electrophoretic deposition, Production of ceramic fibres, Electro-spinning; Drying, Binder burnout, Green machining, Sintering; Sol-gel processing, Thermal and plasma spraying, Thick and thin film coatings- PVD and CVD techniques; Vapor infiltration techniques

(18 Lectures)

Unit IV

Metallic processing: Casting process- major casting techniques, Solidification and volume shrinkage, Casting design and defects, Fundamentals of deformation processing, Deformation work, Hot and cold working, Few forming processes and defects; Metal removal process- Mechanical machining methods, Single and multiple point machining, Introduction to non-traditional machining, Metal joining process- Concepts of Fusion and solid state welding processes, Brazing and soldering, Welding defects; Introduction to powder Metallurgy Design aspects: General principles of materials selection and design based on requirements of function, Property, Processability and cost; Quantitative methods of materials selection, Normalization of properties, Weighting factors, Materials performance index; Design of engineering structures from the atomic- and nano-scales to macroscopic levels; Case studies- modern metallic, ceramic, polymeric and biomaterials devices and components

(16Lectures)

Unit V

Design aspects: General principles of materials selection and design based on requirements of function, Property, Processability and cost; Quantitative methods of materials selection, Normalization of properties, Weighting factors, Materials performance index; Design of engineering structures from the atomic- and nano-scales to macroscopic levels; Case studies- modern metallic, ceramic, polymeric and biomaterials devices and components

(12Lectures)

Course Title: Renewable Energy			
Course Code	MSPHY4007E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

References:

1. P. Boch, J-C. Nièpce, Ceramic Materials: Processes, Properties, and Applications, WileyISTE, 2007.
2. J-H. He, ElectrospunNanofibres and Their Applications, SmithersRapra Technology, 2008.
3. Z. Tadmor, C.G. Gogos, Principles of Polymer Processing, 2nd ed., Wiley International, 2006.
4. T.A.Osswald, Polymer Processing Fundamentals, HanserPublcations, 1998.
5. M.N. Rahaman, Ceramic Processing and Sintering, 2nd ed.,, CRC press
6. F.C. Campbell, Elements of Metallurgy and Engineering Alloys, ASM International, 2008.
7. J. Beddoes, M.J. Bibby, Principles of Metal Manufacturing Processes, Elsevier, 2003.
8. G.E. Dieter, Mechanical Metallurgy,McGraw-Hill,3rd ed.,1986.
9. E. Degarmo, J.T. Black and R.A. Kohser, Materials and Processes in Manufacturing, 9th ed., Wiley, 2002.
10. S. Kalpakjian, S.R. Schmid, Manufacturing Engineering and Technology, 6th ed., Pearson,2009.

Unit-1

Solar Energy: Fundamental and Material Aspects:

Fundamentals of photovoltaic Energy Conversion Physics and Material Properties, Basic to Photovoltaic Energy Conversion: Optical properties of Solids. Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.

(15 Lectures)

Unit-2

Solar Energy: Different Types of Solar Cells:

Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current, Brief description of single crystal silicon and organic and Polymer Solar Cells, Elementary Ideas of Advanced Solar Cells e.g. Tandem Solar cells, Solid Liquid Junction Solar Cells, Nature of Semiconductor, Principles of Photoelectrochemical Solar Cells.

(15 Lectures)

Unit-3

Hydrogen Energy: Fundamentals, Production and Storage:

Relevance in relation to depletion of fossil fuels and environmental considerations. Solar Hydrogen through Photoelectrolysis, Physics of material characteristics for production of Solar Hydrogen. Brief discussion of various storage processes, special features of solid hydrogen storage materials, Structural and electronic characteristics of storage materials. New Storage Modes.

(20 Lectures)

Unit-4

Hydrogen Energy: Safety and Utilization:

Various factors relevant to safety, use of Hydrogen as Fuel, Use in Vehicular transport, Hydrogen for Electricity Generation, Fuel Cells, Various type of Fuel Cells, Applications of Fuel Cell, Elementary concepts of other Hydrogen- Based devices such as Hydride Batteries.

(10 Lectures)

Reference Books:

1. Solar Cell Devices-Physics :Fonash
2. Fundamentals of Solar Cells Photovoltaic Solar Energy :Fahrenbruch & Bube
3. Phoptoelectrochemical Solar Cells: Chandra
4. Hydrogen as an Energy Carrier Technologies Systems Economy : Winter & Nitch (Eds.)
5. Hydrogen as a Future Engery Carrier : Andreas Zuttel, Andreas Borgschulte and Louis Schlapbach

Course Title: Carbon Nanostructures and Their Applications			
Course Code	MSPHY4008E04	**Credits**	4
L + T + P	2 + 0 + 2	**Contact Hours**	30 (L) +60(P) Hours

Unit-I

Introduction to nanomaterials Size Dependent properties. Bulk to Nano Transitions. Method of Synthesis: Thermal and ultrasound decomposition methods. Reduction methods. Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductor nanoparticles. High energy ball milling and mechanical attrition. Thermal evaporation. Sputtering. Laser ablation. Chemical vapour deposition. Molecular beam epitaxy. Thermal spraying. Electro and electroless deposition. Brief description of OD,1D,2D nanomaterials e.g. Quantum wells, wires and dots. Size and dimensionality effects. Excitons. Single electron tunneling. Applications in infrared detectors and quantum dot lasers. Magnetic properties of nanocrystalline materials. Nanostructured ferroelectric materials and their properties.

(15 Lectures)

Unit-II

Carbon Nanostructures: Nature of Carbon Clusters, Discovery of C60, Structure of C60 and its Crystal, Superconductivity in C60, Carbon Nanotubes: Synthesis, Structure, Electrical and Mechanical Properties. Graphene: Discovery, Synthesis and Structural Characterization through TEM, Elementary Concept of its applications. Properties of carbon nanotubes. Inorganic nanotubes and nanorods, nanoporous materials.

(15 Lectures)

List of Experiments

1. Synthesis of nanomaterials through different methods Mecahnical-milling, Sol-gel etc
2. Characterizations of nanomaterial through XRD TEM SEM AFM and other techniques.
3. Synthesis of Carbon Nanotubes through CVD.
4. Characterizations through XRD/TEM
5. Synthesis of Graphene through different methods
6. Characterizations of Graphene through XRD TEM.
7. Different properties of carbon nanostructures.

Course Title: Biomedical Instrumentation			
Course Code	MSPHY4009E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Reference Books:

1. Introduction to Nanotechnology: Poole and Owners
2. Nano Essentials: T. Pradeep
3. Quantum Dots : Jacak, Hawrylak and Wojs
4. Handbook of Nanostructured Materials and Nanotechnology : Nalva (editor)
5. Nano Technology/ Principles and Practices: S.K. Kulkarni
6. Carbon Nanotubes: Silvana Fiorito 6. Nanotechlongy: Richard Booker and Earl Boysen

Unit - I:

Basic principles of biomedical electronics. Distribution of electrical potentials in different parts of the body. Their magnitude and relationship to the physical status. Physical anatomy and its relation to bi-electric signals. Processing of bio-electronic signals and different types of transducers for acquisition.

Recording systems, general consideration of electronic recording amplifier. Pre-amplifier, main amplifier and driver amplifier. Consideration of noise. Different types of digital recorder.

(15 Lectures)

Unit - II:

Need for imaging the human body. Imaging techniques, computer assisted tomography (CATSCAN); Basic principles and overall design. Nuclear resonance techniques; full body nuclear magnetic resonance scanners (NMR);Design of NMR scanner and its applications; Ultrasound instrumentation and its applications; thermography and applications. Case studies of typical instrumentation requirements in Electroencephalography (EEG), Electrocardiography, photo cardiograph, and Electromyography (EMG); Different techniques of displaying information. Display systems. Use of oscilloscope, cardioscope, and multichannel displays. Patient safety, electronic shock hazards in biomedical instrumentation. Leakage current and their merits. Instrumentation grounding techniques and patient monitoring systems.

(15 Lectures)

Unit - III :

Computer based imaging **:** Computer applications in medical imaging : Basics; Computers in nuclear medicine; nuclear medicine computer systems; software in nuclear medicine; digital subtraction radiography; computerised ultrasonography; X-ray computerised tomography; computerised emission tomography; nuclear magnetic resonance.

(15 Lectures)

Unit - IV :

Therapeutic equipments; cardiac pace makers; defibrillators; surgical diathermy;lasers and biomedical electronics; short-wave and microwave diathermy.Computeres in medical research : Signal processing; model building and simulation; Monte Carlo technique; cell kinetics; operational research; statistical research; multivariate analysis; numerical taxonomy; risk profiles; Framingham study; computer networking.

(15 Lectures)

References:

1. R.S. Khandpur, Handbook of Biomedical instrumentation, McGraw-Hill Education, 1987
2. Leslie Cromwell, Biomedical instrumentation and measurements, Prentice-Hall, 2011
3. R.D. Lele, Computers in medicine, Tata McGraw-Hill Pub., 1988

Course Title: Industrial Process Control			
Course Code	MSPHY4010E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Unit - I:

Transducer and Instrumentation Basics: Principles of transduction, resistive, capacitive, inductive, piezoelectronic, digital etc. temperature, strain, pressure and flow transducers mounting, characteristics and responses.Digital transducers, digital encoders rotating optical transducer, level transducer.Signal conditioning system, offsetting linerization, linear variable differential transducer (LVDT). Instrumentation amplifiers, differential input and DC instrumentation amplifiers. Data Acquisition and Conversion Systems : Microprocessor bases data acquisition system S/H circuits, Analog multiplexers, DAC & ADC converters, signal channel and multichannel IC's, successive approximation register (SAR), converter specifications, resolution, accuracy and speed, recorders, display systems.

(15 Lectures)

Unit - II :
Industrial Process Control : Basic process elements, process model identification, feedback control system, feedback and feed forward and cascade control, Analog controllers, Proportional Integral derivative (PID) controller, Turning of analog controllers.

(15 Lectures)

Unit - III :
Micro Controllers : Logic control systems, Programmable Logic Controller (PLD), basic functions of PIC, basic architecture, ladder diagram, programming, mirocontroller8031/8051, a elements of 16 bit microcontroller (8097).Alarm signal generation for a process (e.g. heating etc.,) Direct digital control (DDC) algorithm.

(15 Lectures)

Unit - IV:
Interfacing - Standards for Instrumentation : Analog signal transmission, 4.20 mA current loop, Digital transmission, synchronous/asynchronous (8251 USART), parallel data transmission (PPI 8255), control parallel printer prot. Bus standards : 222 C, Rs-422, IEE 802.4, General purpose interfaced bus (GPIB), IEE 488. Interfacing with stepper motor. Interfacing with DAC & ADC.

(15 Lectures)

References :

1. D.V.Hall, Microprocessors and Interfacing, Tata McGraw Hill Education Private Limited, 2005
2. Barry E. Jones, Instrumentation measurement and feedback, Tata McGraw Hill Education Private Limited, 1977

Course Title: Nanoelectronics			
Course Code	MSPHY4011E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I:
Nanoelectronics: Why? Device scaling, Moore's law, limitations, role of quantum mechanics, Nanostructures: Impact, technology and physical consideration; Mesoscopic observables
Preliminaries : Basic Quantum mechanics and Fermi statistics, Metals, Insulators and Semiconductor, Density of states (DOS) in 0D, 1 D, 2D and 3D, DOS in disordered materials, Physics of organic semiconductors: concept of HOMO and LUMO, band gap etc. Novel molecules (Pentacene, carbon nanotube, Fullerenes and its derivatives etc.) and conjugated polymers (Polyacetylene, P3HT, PEDOT:PSS etc.).

(15 Lectures)

UNIT II:
Semi-classical theory of transport in nanostructures: *Modification of Ohm's law*: elastic resistor, ballistic and diffusive transport, conductivity, quantum capacitance, diffusion equation for ballistic transport, Nanotransistor. Voltage-drop, Quasi-Fermi levels, Landauer formula, electrostatic potential versus electrochemical potential, Boltzmann transport equation. Spin voltages.
Entropy driven processes in electrical transport, Seebeck effect, Peltier effect, Heat current, second law of thermodynamics, entropy.

(15 Lectures)

UNIT III:

Two terminal quantum dot and quantum wire devices: Equilibrium in two terminal devices, Current flow in the presence of a bias, numerical technique for self-consistent estimation of V-I ,Current flow, quantum of conductance.

Three-terminal devices: Field Effect Transistors (FETs): Ballistic quantum wire FETs, conventional MOSFETs, CMOS, short channel and narrow width, hot electron effect, punch-through and thin gate oxide breakdown, OFET;

Spintronics: Spin, propagation, detection, spinFETs.

(15 Lectures)

UNIT IV:
Nano-fabrication techniques: Top-down and bottom-up strategies, advantages/disadvantages/ limitations, e-beam lithography, Focussed Ion beam milling, self-organized structures, laser nano-patterning, nano-imprint, electrochemical synthesis, Fabrication of OEDs etc.

(15 Lectures)

References

1. David Ferry , Transport in Nanostructures Cambridge University Press (1995)
2. M. Baldo, Introduction to Nanoelectronics (Lecture Notes; May 2011 MIT).
3. S. Datta, Electronic Transport in Mesocopic Systems; Cambridge University Press (1995).
4. S. Datta, Quantum Transport: Atom to Transistor; Cambridge University Press (2005).
5. M. Lundstrom and J. Guo, Nanoscale Transistors; Physics, Modeling, and Simulation, Springer (2006).
6. P.W. Atkins and R.S. Friedman, Molecular Quantum Mechanics; Oxford University Press, 3rd edition (1997).
7. M. Stepanova and S. Dew, Nanofabrication: Techniques and Principles; Springer-Verlag (2012)

Master of Science (M.Sc.) Physics Programme

Detailed Syllabus

(Effective from Academic Session 2020-2021)

SEMESTER - III

Specialization

Nuclear and Particle Physics

Course Title: Advanced Nuclear Physics			
Course Code	MSPHY3101C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I

Two-body bound state : Properties of deuteron, Schrodinger equation and its solution for ground state of deuteron, spin dependence of nuclear forces, electromagnetic moment and magnetic dipole-moment of deuteron and the necessity of tensor forces.

(8 Lectures)

UNIT II

Nuclear models and stability : Mean potential, Bethe-Weizsäcker binding energy/mass formula, Fermi gas model, Shell model, Magic Numbers, Collective model, β-instability, α-instability, Nucleon emission, production of super-heavy elements.

(12 Lectures)

UNIT III

Nuclear reactions : Cross-sections, Classical scattering on a fixed potential, Quantum mechanical scattering on a fixed potential, Particle-particle scattering, Nucleon-nucleus and nucleon-nucleon scattering, Resonance scattering and reactions−Breit-Wigner dispersion relation; Compound nucleus formation and break-up, Coherent scattering and the refractive index, Statistical theory of nuclear reactions. Optical model for nuclear reactions at low energies, comparison with experiments.

(16 Lectrures)

UNIT IV

Experimental Techniques : Charge particle, neutron, and gamma-ray Spectroscopy, methods for charge and mass identification : δE-E, TOF, mass spectrometer, Neutron: TOF and n-discrimination, Gamma-rays : Coincidence technique, Detector array, Multiplicity, Doppler shift and Doppler broadening, Methods for life time measurements: Delay coincidence, pulse beam, recoil distance and Doppler shift attenuation, isomeric shift and lamb shift.

(14 Lectrures)

UNIT V

Application of Nuclear Techniques : Mossbaurer effect and its applications, Activation method, Biological effect of radiation, Industrial and Analytical application, nuclear medicine.

(10 Lectrures)

References Books:

1. *Introduction to Nuclear Physics*, Kenneth Krane, Wiley India Pvt. Ltd.
2. *Introduction to Nuclear Physics*, H. A. Enge, Eddison Wesley
3. *Nuclei and Particle*, E. Segre, W. A Benjamin,
4. *Concepts of Nuclear Physics*, B. L. Cohen
5. *Nuclear Physics, Experimental and Theoritical*, H. S. Hans, New Age International
6. *Introduction to Nuclear and Particle Physics*, A. Das & T. Ferbel, World Scientific
7. *Nuclear and Particle Physics*, W. E. Burcham and M. Jobes, Addison Wesley
8. *Nuclear Physics*, S. N. Ghoshal, *Nuclear Physics* - D. C. Tayal
9. *Nuclear Physics* - An Introduction, S. B. Patel, New Age International

Course Title: Nuclear and Particle Physics Lab. – I			
Course Code	MSPHY3102C04	**Credits**	4
L + T + P	0 + 0 + 4	**Contact Hours**	120 (P)

- List of experiments :

1. **G. M. Counters – characteristics, dead-time and counting statistics**

   Apparatus:- Geiger Muller Detector, Geiger Muller Counter (G. M Counter), G. M. Detector Stand, Desktop and Cable

2. **Verify the inverse square relationship between the distance and intensity of radiation using GM Counter.**

   Apparatus:- Geiger Muller Detector, Geiger Muller Counter (G. M Counter), G. M. Detector Stand, Desktop and Cable

3. **Spark counter-characteristics and range of x-particles in air**

   Apparatus:- Spark counter whole Setup

4. **NaI(Tl) – Calibration and characteristic study, resolution and determination of gamma ray energy**

   Apparatus:- NaI Detector, Scintillation Preamplifier, NIM Crate, NIM High Voltage, Multichannel analyzer, Desktop and Cables

5. **Setup the coincidence circuit in the a cosmic muon test bench**

   Apparatus:- Plastic Scintillator Panel, NIM Crate, NIM High Voltage, NIM Discriminator, NIM Counter, NIM Coincidence unit, NIM Gate generator and Cables

6. **Alpha spectroscopy using a Si surface-barrier detector:**

   Energy response & Energy resolution measurements. (b) Its characteristics and applications. (c) Measurement of stopping power of an alpha particle

   Apparatus:- Si surface-barrier detector attached with Vacuum chamber, Pre-amplifier, MAC, Counter, Si surface-barrier detector High Voltage Setup, Multichannel analyzer, Desktop and Cables

7. **Identification of unknown gamma ray source using known gamma emitter sources with the help of NaI(Tl) detector.**

   Apparatus:- NaI Detector, NIM Crate, NIM High Voltage, Multichannel analyzer, Desktop and Cables

8. **Angular correlation ratio using NaI(Tl) detector.**

Apparatus:- Two NaI Detector, NIM Crate, NIM High Voltage, NIM Discriminator, NIM Counter, NIM Co-Incident unit, NIM Gate generator, a Goniometer to orient the detector system and Cables

9. **Design the simple geometry of give detector setup and visualize in Geant4.**

   Apparatus:- Desktop

10. **Absorption of γ - rays – Determination of the Half-value Thickness of Absorber Materials (Pb, Al, Fe)**

    Apparatus:- Geiger Muller Detector, Geiger Muller Counter (G. M Counter), G. M. Detector Stand, Desktop, Lead, Aluminum Absorber and Iron Set of absorbers and Cable.

❖ Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Advanced Particle Physics			
Course Code	MSPHY3103C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I

A Preview of Particle Physics : Fundamental Building Blocks and their nature of Interactions, Classification of elementary particles by masses, Conservation Laws: Energy, Angular Momentum, electromagnetic Charge, Lepton flavor and Baryon Numbers. Natural units system, Relativistic kinematics.

(5 Lectrures)

UNIT II

Symmetries and Quarks : Symmetries in Physics, Symmetries and Groups (Brief Introduction), Group SU(2), Combining Representations, Finite Symmetry Groups: P and C, SU(2) of Isospin, Isospin for Antiparticles, Group SU(3), Example of an SU(3) Group: Isospin and Strangeness, Quark-Antiquark States : Mesons, Three-Quark States: Baryons, Magnetic Moments, Heavy Quarks: Charm and Beyond, Hadron Masses, Color Factors.

(10 Lectrures)

UNIT III

QUANTUM ELECTRODYNAMICS (QED) : Structure of the QED Lagrangian, gauge invariance and conserved current, scalar electrodynamics, Feynman rules for QED, phase space integration, Casimir's Trick and the Trace Theorems, Miller and Bhabha scattering, polarisation vectors, Compton scattering and pair creation/annihilation, Klein Nishina formula, Higher Orders in QED: Concept of multi−loop diagrams (no computation), momentum integral, UV and IR singularities, idea of regularisation, running coupling constant.

(15 Lectures)

UNIT IV

QUARK PARTON MODEL : Isospin and strangeness, introduction to unitary groups, generators, Casimir invariants, fundamental and adjoint representations, root and weight diagrams, meson and baryon octets, baryon decuplet, Gell− Mann−Nishijima formula. symmetry group, Young tableaux, quark model, Deep Inelastic Scattering, Elastic scattering off a point particle, Rosenbluth formula, Breit frame, inelastic scattering, structure functions, dimensionless variables. Bjorken scaling, parton model, structure functions in terms of PDFs, Callan−Gross relation, kinematic regions, valence and sea quarks, gluons.

(15 Lectures)

UNIT V

WEAK INTERACTIONS : Fermi theory of Beta decay, Fermi and Gamow −Teller transitions, current−current form of weak interactions, Fermi constant, universality, unitarity violation at high energies. Intermediate vector bosons, unitarity, requirement of conserved currents, muon decay, pion decay, Parity violation, experiments of Wu et al and of Goldhaber et al, maximal parity violation, CP Violation.

(10 Lectures)

UNIT VI

Course Title: Introduction of Astrophysics			
Course Code	MSPHY3104E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Particle detectors and accelerators : Cloud and bubble chambers, emulsion techniques, electronic detectors, proportional counters, fixed target and collider experiments, basic idea of cyclotron, synchrotron and linac.

(10 Lectures)

References :

1. Introduction to Elementary Particles by D. Griffiths (2nd Ed., Wiley-VCH, 2008).
2. Quarks and Leptons, by F. Halzen and A.D. Martin (Wiley 1984).
3. Particle Physics, by B.R. Martin and G. Shaw (Wiley 2008).
4. Elementary Particle Physics by S. Gasiorowicz (John Wiley, 1966)
5. Elementary Particles and the Laws of Physics by R. P. Feynman and S. Weinberg (Cambridge University Press, 1999)
6. Introduction to Elementary Particle Physics by A. Bettini (Cambridge University Press, 2008)

UNIT I

Stellar Structure and Evolution : Stellar Structure and Evolution: Virial Theorem, Formation of Stars, Hydrostatic Equilibrium, Integral Theorems on pressure, density and temperature, Homologous Transformations, Polytropic gas spheres Lane Emden Equation and its solution, Energy generation in stars, P-P and C-N cycles, Radiative and Convection transport of energy, Equations of stellar structure and their solution, Evolution of stars of different masses, pre- and post main- sequence evolution.

(20 Lectures)

UNIT II

Gravitational Collapse and relativistic Astrophysics : Newtonian theory of stellar equilibrium, White Dwarfs, Electron degeneracy and equation of States, Chandrasekhar Limit, Mass-Radius relation of WD. Neutron Stars, Spherically symmetric distribution of perfect fluid in equilibrium. Tolman-Oppenheimer-Volkoff (TOF) equation, Mass-Radius relations of NS. Pulsars, Magnetars, Gamma ray bursts. Black holes, Collapse to a black hole (Oppenheimer and Snyder), event horizon, singularity.

(10 Lectures)

UNIT III

Galaxies : The milky way Galaxy, Distribution of stars, Morphology, Kinematics, Interstellar medium, Galactic center. Classification of galaxies, Hubble sequence, Ellipticals, Lenticularsand spiral galaxies and their properties, distribution of light and mass in galaxies.

(10 Lectures)

UNIT IV

Overview of Modern Astronomy : 21-cm hydrogen line, cosmic radio sources, quasars, gravitational lensing, Expansion of the Universe and determination of Hubbles constant, gamma ray bursters. Sources of Gravitational Waves.

(10 Lectures)

UNIT V

Experimental methods in Nuclear Astrophysics : Coulomb dissociation, Trojan Horse Method, ANC method, recent applications using Radioactive beams.

(5 Lectures)

References:

1. Stellar Interiors - Physical Principles, Structure, and Evolution by C. J. Hansen, S. D. Kawaler, V. Trimble (Springer, 2004)
2. Stellar Structure and Evolution by R. Kippenhahn and A. Weigert (Springer, 1996)
3. Basics of Astronomy – IGNOU course book PHE-15 Astronomy and Astrophysics, 2006
4. Modern Astrophysicsby Carrol & Ostlie (Addison Wesley, 1996)
5. The Physical Universe by F. Shu (University Science Books, 1982)
6. Principles of Stellar Structure Vol. I & II by J. P. Cox & R. T. Giuli (Gordon & Breach, 1968)
7. An Introduction to the Study of Stellar Structure by S. Chanrdrasekhar (Dover, 1968)
8. Stellar Interiors by D. Menzel, P. L. Bhatnagar & H. K. Sen (Chapman & Hall, 1963)
9. Galactic Astronomy by J. Binney & M. Merrifield (Princeton Univ. Press, 1998)
10. Textbook of Astronomy & Astrophysics by V. B. Bhatia (Narosa, 2001)

Course Title: Nuclear Reactor Physics			
Course Code	MSPHY3105E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I

Nuclear energy and Neutron diffusion : Binding energy - Nuclear reactions - Nuclear cross sections, Macroscopic cross sections, Mechanism of fission, Products of fission - Energy release from fission - Reactor power - Fuel burn up, Consumption - Multiplication factor - neutron balance and conditions for criticality - Conversion and breeding Classification of reactors.

(10 Lectures)

UNIT II

Diffusion of neutrons : Flux and current density - Equation of continuity - Fick's law - Diffusion equation – Boundary conditions and solutions - Diffusion length - Reciprocity theorem.

(10 Lectures)

UNIT III

Neutron moderation : Energy loss in elastic collision - moderation of neutrons in Hydrogen - Lethargy - Moderation of neutrons - Fermi's age theory - Moderation with absorption. Fermi theory of Bare thermal reactor : Criticality of an infinite reactor - One region finite thermal reactor - Critical equation - Optimum reactor shape.

(10 Lectures)

UNIT IV

Reactor kinetics : Infinite reactor with and without delayed neutrons - Stable period - Prompt jump - Prompt criticality - Negative reactivity - Changes in reactivity - Temperature coefficient - Fission poisoning.

(10 Lectures)

UNIT V

Control and shielding : Control Rod , Fuel management, Natural reactors, Thermal reactors - Intermediate reactors, Fast reactors Breeding, The Thorium converter Light water.

(10 Lectures)

UNIT VI

Reactors : Heavy water Reactors Heat generation and removal Radiation shielding and reactor safeguards Evolution of reactors -Reactor properties over life - core life estimation.

Course Title: Statistical Analysis Techniques in Nuclear and Particle Physics			
Course Code	MSPHY3106E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

(10 Lectures)

References:

1. John.R Lamarsh, Introduction to Nuclear Reactor Theory, Addison Wesley Publishing Company 2nd printing (1992)
2. Paul .F. Zweifel, Reactor Physics, McGraw Hill Book Company (1973) India.
3. Richard Stepheson, Introduction to nuclear Engineering, McGraw Hill Book Company (1974) New York.
4. Suresh Gard, Feroz Ahmed and L. S Kothari, Physics of Nuclear Reactors, Tata McGraw Hill Pub. Co. Ltd, London.
5. Samuel Glasstone and Edmund , Nucleaar reactor theory

UNIT I

Probability theory: Classical probability, Frequentist probability, Subjective (Bayesian) probability, Komogorov axiomatic approach, Probability distributions, PDFs in more dimensions, Mean, variance and covariance, General Properties of Distributions Binomial Distribution, Poisson Distribution, Gaussian Distribution, Chi-Square (χ^2) Distribution, Gamma Distribution, Commonly used distributions, Conditional probability, Bayes theorem, The likelihood function.

(15 Lectures)

UNIT II

Inference : Review: Random Errors, Error Propagation, Systematic Errors, Basic Estimators, Maximum Likelihood, Inference: Bayesian inference, Error propagation with Bayiesian inference, Choice of the prior, Frequentist inference, Maximum likelihood estimates, Estimate of Gaussian parameters, Estimator properties, Neymans confidence intervals, Binomial intervals, Approximate error evaluation for maximum likelihood estimates, Two-dimensional uncertainty contours, Likelihood function for binned samples, Combination of measurements, Hypothesis tests

(15 Lectures)

UNIT III

Essential Statistics for Data Analysis : Measures of Centrality, Measure of Dispersion, LEAST SQUARES, Fitting Binned Data, Linear Least Squares and Matrices, Chi-Square (χ^2) Test, Students t Test, Simple Linear Regression, Nonlinear Regression, Correlation, Time Series Analysis, Frequency Domain Analysis, Counting Statistics.

(15 Lectures)

UNIT IV

Hypothesis tests and Discoveries Level : The Neyman Pearson lemma, Projective likelihood ratio, Fisher discriminant, Artificial Neural Net-work, Boosted Decision Trees, Overtraining, Upper limits and Discoveries level: Poisson upper limit, Feldman Cousins intervals, Upper limits for event counting experiments, The modified frequentist approach, Treatment of nuisance parameters, Profile likelihood, Variations on test statistics, Random Number generator, Review of Monte Carlo Monte Carlo technique.

(15 Lectures)

References:

1. Statistics for Nuclear and Particle Physicists, Louis Lyons, Cambridge University Press (2018)
2. Statistical Methods in Experimental Physics, Frederick Jame, World Scientific Publishing Co. Pre. Ltd (2nd Edition).
3. Data Analysis in High Energy Physics: A Practical Guide to Statistical Methods, edited by Olaf Behnke, Kevin Kröninger, Grégory Schott, Thomas Schörner-Sadenius, Wiley & sons
4. Statistical Methods for Data Analysis in Particle Physics, Luca Lista, Springer.

Course Title: Radiation Safety			
Course Code	MSPHY3107E02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

UNIT I

Interactions of Radiation with Matter : Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric effect, Compton scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), interaction of neutrons with matter.

(10 Lectrures)

UNIT II

Radiation Quantities and Units : Activity (Becquerel and Curie), energy, exposure (C/kg and Roentgen), air kerma, absorbed dose (Gray and rad), radiation weighting factors, tissue weighting factors, equivalent dose (Siever and rem), effective dose (Sievert and rem) Biological Effects of Radiation Introduction to cell, direct and indirect interactions, effects of radiation on living cells, chromosomal aberration, somatic and genetic effects, deterministic and stochastic effects, acute and chronic exposure, partial body and whole body exposures.

(10 Lectrures)

UNIT III

Radiation Hazard Evaluation and Control : Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation: individual and work place monitoring, application of time, distance and shielding; shielding material, exposure rate constant, types of radiography installations: enclosed installation, opentop, open field; planning of radiography enclosure, controlled areas and supervised areas, shielding calculation for enclosed installations, scattering, Albedo, skyshine, calculation of cordon-off distance, safety in radiography installations: enclosed, open top and field radiography, tracking of lost sources, source storage facilities, safe work practices, safety aspects of high energy accelerators,

(10 Lectrures)

References

1. Radiation Safety: Management and Programs, Haydee Domenech , Springer 2017 edition .
2. Radiation Safety Procedures and Training for the Radiation Safety Officer: Guidance for Preparing a Radiation Safety Program, by John R Haygood, iUniverse (17 September 2013).
3. Radiation Safety in Nuclear Medicine, A Practical, Concise Guide, Gopal B. Saha, Springer.
4. Physics for Radiation Protection, James E. Martin, Wiley- VCH Verlag GmbH & Co. KGaA .
5. Applied Physics of External Radiation Exposure, Dosimetry and Radiation Protection, Antoni, Rodolphe, Bourgois, Laurent, Springer.

Course Title: Neutrino Physics			
Course Code	MSPHY3108E02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

UNIT I

Important historical experiments : Birth of the neutrino, Nuclear recoil experiment by Rodeback and Allen, Discovery of the neutrino, solar neutrino detection parity violation in weak interactions, helicity of the neutrino, Discovery of weak neutral currents, Discovery of the weak gauge bosons W and Z Observation of neutrinos from SN 1987A, Number of neutrino flavours from the width of the Z bosons. Dirac and Majorana mass terms, Experimental status of lepton number violation.

(10 Lectrures)

UNIT II

Neutrino oscillations : General formalism, C P and T violation in neutrino oscillations, Oscillations with two neutrino flavours, The case for three flavours, Experimental considerations, Nuclear reactor experiments, Experimental status, Accelerator-based oscillation experiments: LSND, KARMEN, Future test of the LSND evidenceMiniBooNE Searches at higher neutrino energy: CHORUS and NOMAD Neutrino oscillations in matter, C P and T violation in matter, Possible future beams: Off-axis beams and experiments, Beta beams, Superbeams, Muon storage rings neutrino factories.

(10 Lectrures)

UNIT III

Important historical experiments : Direct neutrino mass searches, Fundamentals of -decay: Matrix elements, Phase space calculation, Kurie plot and ft values, Searches for m_{ν} : General considerations, Searches using spectrometers Cryogenic searches, Kinks in -decay, $m_{\nu\mu}$ determination from pion-decay Mass of the ν_{τ} from tau-decay, Electromagnetic properties of neutrinos: Electric dipole moments, Magnetic dipole moments, Neutrino Radiative decay.

(10 Lectrures)

References

1. K. Zuber, "Neutrino Physics", IoP Publishing 2004.
2. C. Giunti and C.W.Kim, "Fundamentals of Neutrino Physics and Astrophysics", Oxford University Press, 2007.
3. R. N. Mohaptara and P. B. Pal, "Massive Neutrinos in Physics and Astrophysics", World Scientific (2ndEdition), 1998
4. H.V. Klapdor-Kleingrothaus & K. Zuber, "Particle Astrophysics",IoP Publishing, 1997.
5. Scientific American articles:"Detecting Massive Neutrinos", E. Kearns, T. Kajita, Y. Totsuka, Scientific American, August 1999."Solving the Solar Neutrino Problem", A.B. McDonald, J.R. Klein, D.L. Wark, Scientific American, April 2003.

Master of Science (M.Sc.) Physics Programme

Detailed Syllabus

(Effective from Academic Session 2020-2021)

SEMESTER - IV

Course Title: Experimental Techniques in Nuclear and Particle Physics			
Course Code	MSPHY4101C04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

Specialization

Nuclear and Particle Physics

UNIT I

Detection of radiations : Interaction of gamma-rays, electrons, heavy charged particles, neutrons, neutrinos and other particles with matter. General properties of Radiation detectors, energy resolution, detection efficiency and dead time. Statistics and treatment of experimental data. Gas-filled detectors, Proportional counters, space charge effects, energy resolution, time characteristics of signal pulse, position-sensitive proportional counters, Multiwire proportional chambers, Drift chamber, Time projection chamber. Organic and inorganic scintillators and their characteristics, light collection and coupling to photomultiplier tubes and photodiodes, description of electron and gamma ray spectrum from detector, phoswich detectors, Cherenkov detector. Semiconductor detectors, Ge and Si(Li) detectors, Charge production and collection processes, detector structures and fabrication aspects, semiconductor detectors in X- and gamma-ray spectroscopy, Pulse height spectrum, Compton-suppressed Ge detectors, Semiconductor detectors for charged particle spectroscopy and particle identification, Silicon strip detectors, Radiation damage. Electromagnetic and Hadron calorimeters. Motion of charged particles in magnetic field, Magnetic dipole and quadrupole lenses, beta ray spectrometer. Detection of fast and slow neutrons - nuclear reactions for neutron detection. General Background and detector shielding.

(20 Lectrures)

UNIT II

Electronics associated with detectors : Electronics for pulse signal processing, CR-(RC) n and delay-line pulse shaping, pole-zero cancellation, baseline shift and restoration, preamplifiers (voltage and charge-sensitive configurations), overload recovery and pileup, Linear amplifiers, single-channel analyser, anolog-to-digital converters, multichannel analyzer. Basic considerations in time measurements, Walk and jitter, Time pickoff methods, time-to-amplitude converters, Systems for fast timing, fast-slow coincidence, and particle identification, NIM, VMI and PXI instrumentation standards and data acquisition system.

(20 Lectures)

UNIT III

Experimental methods : Detector systems for heavy-ion reactions : Large gamma and charge particle detector arrays, multiplicity filters, electron spectrometer, heavy-ion reaction analysers, nuclear lifetime measurements (DSAM and RDM techniques), production of radioactive ion beams. Detector systems for high energy experiments : Collider physics (brief account), Particle Accelerators (brief account), Secondary beams, Beam transport, Modern Hybrid experiments-CMS and ALICE.

(20 Lectures)

References

1. Introduction to Experimental Particle Physics by Richard Fernow (Cambridge University Press), 2001.
2. Radiation detection and measurement by Glenn F. Knoll (Wiley), 2010.
3. Techniques in Nuclear and particle Experiments by W.R. Leo (Springer), 1994.
4. Detectors for particle radiation by Konrad Kleinknecht (Cambridge University Press), 1999.

Course Title: Nuclear and Particle Physics Lab. – II			
Course Code	MSPHY4103C04	**Credits**	4
L + T + P	0 + 0 + 4	**Contact Hours**	120 (P)

❖ List of experiments :

1. **Determination of the Muon Lifetime**

   Apparatus:- Plastic Scintillator Panel, NIM Crate, NIM High Voltage, NIM Discriminator, NIM Counter, NIM Co-Incident unit, NIM Gate generator , Oscilloscope and Cables

2. **Relative efficiency of beta and gamma rays using GM counter and feather comparison method to find range of unknown beta source.**

   Apparatus:- Geiger Muller Detector, Geiger Muller Counter (G. M Counter), G. M. Detector Stand, Sliding bench for G. M. Detector, Desktop and Cables

3. **Measurement of the half-life of meta-stable Barium-137**

   Apparatus:- Geiger Muller Detector, Geiger Muller Counter (G. M Counter), G. M. Detector Stand, Desktop and Cable

4. **To study absorption of beta rays in Al and deduce end-point energy of a beta emitter.**

   Apparatus:- Geiger Muller Detector, Geiger Muller Counter (G. M Counter), G. M. Detector Stand, Aluminum Absorber, Desktop and Cable

5. **Study of angular distribution of Compton scattered gamma rays using scintillation spectrometer.**

   Apparatus:- NaI detector with amplifier and accessories, Scatterers of aluminum, copper and steel, Lead bricks , A rotational stage to move the detector at various angles with respected to collimated beam, Multichannel analyzer system, Desktop and Cable

6. **Proportional counter, its energy response and low energy X-ray measurements**

   Apparatus:- Proportional counter, Proportional Preamplifier, NIM Crate, NIM High Voltage, Multichannel analyzer, Desktop and Cables

7. **Measurement of the Cosmic Ray Flux**

   Apparatus:- Plastic Scintillator Panel, NIM Crate, NIM High Voltage, NIM Discriminator, NIM Counter, NIM Co-Incident unit, NIM Gate generator, Oscilloscope and Cables

8. **Study of passage of particle through matter using Geant4**

   Apparatus:- Geant4 simulation package, and Desktop

9. **$LaBr_3$ – Calibration and characteristic study, resolution and determination of gamma ray energy**

Apparatus:- $LaBr_3$- Detector, NIM Crate, NIM High Voltage, Multichannel analyzer, Desktop and Cables

10. Simulation and characterization of silicon detectors.

Apparatus:- Silicon- Detector, NIM Crate, NIM High Voltage, Multichannel analyzer, Desktop and Cables

- ❖ Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Particle Accelerator Physics			
Course Code	MSPHY4104E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I

Charged Particle Dynamics : Particle motion in electric and magnetic fields, Beam transport system, Beam pulsing and bunching techniques, microbeams, Particle and ion sources, secondary beams, Measurement of beam parameters.

(10 Lectures)

UNIT II

Radiofrequency Accelerators : Linear accelerators **-** Resonance acceleration and phase stability, electron and proton Linacs. Circular accelerators- Cyclotron, Frequency Modulated Synchrocyclotron, AVF Cyclotron, Alternating-gradient accelerators.

(15 Lectures)

UNIT III

Electrostatic and Heavy Ion Accelerators : Van de Graaff voltage generator, Cockcroft-Walton voltage generator, insulating column, voltage measurement, Acceleration of heavy ions, Tandem electrostatic accelerator, Production of heavy negative ions, Pelletron and Tandetron, Cluster beams, Superconducting Heavy Ion Linear Accelerators.

(15 Lectures)

UNIT IV

Synchrotron Radiation Sources : Electromagnetic radiation from relativistic electron beams, Electron synchrotron, dipole magnet, multipole wiggler, noncoherent and coherent, Undulator, Characteristics of synchrotron radiation.

(10 Lectures)

UNIT V

Radioactive ion beams : Production of Radioactive ion beams, Polarized beams, Proton synchrotron, Colliding accelerators. Applications : Use of accelerators and Ion-beam Analysis Techniques.

(10 Lectures)

References

1. Particle Accelerator Physics, Vol I and II, H.J. Wiedman, (Springer Verlag), 1998.
2. Particle Accelerators, M.S. Livingston and J.P. Blewel, (McGraw-Hill Book Press), 1962.
3. Nuclear Spectroscopy and Reactions Part-A, Ed. J. Cerny, (Academic Press), 1974.
4. Theory of Resonance Linear Accelerators by I.M. Kapchenkey, (Harwood Academic Publishers).

Course Title: Data Analysis and Simulation in particle Physics			
Course Code	MSPHY4105E04	**Credits**	4
L + T + P	4 + 0 + 0	**Contact Hours**	60 (L) Hours

UNIT I

C/C++ Programming concepts : Overview- Fundamentals of computer architecture and operation - Programming inC and C++ languages - Data types, int, char, float etc. - C expressions, arithmetic operations, relational and logic operations - Concepts of variables, statements and function calls - Assignment statements, extension of assignment to the operations - primitive input output and print functions – conditional execution using if, else. switch and break statements- Concepts of loops, for, while and do-while-Arrays and pointers- One/Two dimensional arrays and example of iterative programs using arrays-Matrix computations- Sub-programming, functions- Strings -Structure and unions.- Defining C structures, passing structures as arguments- File 1 /0-Simple programs.

(15 Lectures)

UNIT II

Data Analysis : Reconstruction of raw detector data, Charged-particle trajectories, Energy reconstruction, Quark jets, Stable-particle identification, Displaced vertices, unstable-particle reconstruction, Monte Carlo event generators, detector response, Beyond the detector, Multivariate techniques.

(15 Lectures)

UNIT III

Software for Data Analysis : Standard Analysis Packages, Cern Root, Basic idea of ROOT: Histogram, Graph, fitting to Pseudo Data, A Little C++, Math Libraries in ROOT, Linear Algebra in ROOT Trees:Data Handling, Organization, Storage, Data Analysis Capabilities.

(15 Lectures)

UNIT IV

GEANT4 Simualtion : Geant4 Scope of Application, Overview of Geant4 Functionality including tracking, geometry, physics models and hits. Examples: nuclear physics and medical physics.

(15 Lectures)

References

1. E. Balgurusamy : Programming in ANSI C, Tata McGraw Hill
2. V Rajaraman, Computer Oriented Numerical Methods, 3rd Ed. (Prentice-Hall, New Delhi, 1993).

3. https://root.cern.ch/guides/users-guide

4. https://geant4.web.cern.ch/support/user_documentation

Course Title: General Theory of Relativity			
Course Code	MSPHY4107E02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

UNIT I

Equality of gravitational and intertial masses. Equivalence principle. Principle of general covariance.

(5 Lectures)

Unit II

Tensor Analysis : covariant and contravariant tensors. Tensors of arbitrary rank. Metric tensor. Parallel transport and covariant differentiation. Affine connection and its relation to metric tensor. Curvature tensor and its symmetries. Bianchi identities. Weyl tensor and conformal invariance.

(10 Lectures)

Unit III

Geodesics: Equation of motion of particles. Weak fields and Newtonian approximation. Time and distance in general theory, gravitational red and blue shifts, experimental verification, Einstein’s field equation - Newtonian gravity as an approximation, Schwarzschild solution, Radial motion towards centre. Nature of singularities, black holes, even horizon, Kruskal co-ordinates.

(15 Lectures)

Unit IV

General orbits, constants of motion, deflection of light, precession of perihelion and radar echo. Standard, isotropic and harmonic coordinates. Parametrized post-Newtonian formalism and status of observational verification. Mach’s principle.

(15 Lectures)

Unit V

Energy momentum tensor for a perfect fluid, equation of motion from field equation for equation for dust. Action principle for field equations. Conservation laws in curved space and pseudo energy tensor for gravitational field .

(15 Lectures)

References

1. Introducing Einstein's Relativity by Ray D'Inverno (Clarendon Press, 1992)

2. Principles of Gravitation and Cosmology, by M. Berry (Cambridge University Press, 1976)
3. Introduction to General Relativity & Cosmology, by Steven Weinberg (John Wiley & Sons, 1972)
4. The Classical Theory of Fields by L.D. Landau and E. M. Lifshitz (Pergamon, 1975)
5. Classical Fields: General Relativity and Gauge Theory by Moshe Carmeli (World Scientific, 2001)
6. General Theory of Relativity by P.A. M. Dirac (John Wiley, 1975)
7. Gravity, Black Holes and the Very Early universe: An Introduction to General Relativity and Cosmology by Tai L. Chow (Springer, 2008)

Course Title: High Energy Cosmic Ray			
Course Code	MSPHY4107E02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

UNIT I

The Birth of Cosmic Ray: Stellar evolution, the pp chain, Supernova explosions, Supernova neutrinos, Supernova remnants, Acceleration of cosmic rays: stochastic acceleration of charged particles, particle acceleration at astrophysical shocks, acceleration with energy loss.

(10 Lectures)

UNIT II

Cosmic Ray Interaction : Strong, electromagnetic and weak interaction and weak interactions, Units of energy and interaction, Electromagnetic process in matter: Coulomb scattering, Ionization loss, Cherenkov light, Compton scattering, Bremsstrahlung, creation of electron-positron scattering, Synchrotron radiation, Inverse Compton effect, kinematics variables and invariant cross-section.

(10 Lectures)

UNIT III

Ultra High Energy Cosmic Ray (UHECR) : Cosmic microwave background, UHECR interactions on the microwave background, Propagation of UHE protons and nuclei, Possible astrophysical sources of UHECR, GZK cutoff, current status of the field, High energy neutrino and gamma-ray astronomy (review).

(10 Lectures)

References

1. High Energy Cosmic Rays , Todor stanev, Springer
2. Cosmic Rays and Particle Physics, By Thomas K. Gaisser, Cambridge University Press.
3. High Energy Radiation from Black Holes: Gamma Rays, Cosmic Rays, and Neutrinos, By Charles D. Dermer, Charles Dermer, Govind Menon, Princeton University Press.
4. Ultra-high Energy Particle Astrophysics, By Shigeru Yoshida, Nova Science Publishers, Inc. New York.

Course Title: Dark Matter Physics			
Course Code	MSPHY4108E02	**Credits**	2
L + T + P	2 + 0 + 0	**Contact Hours**	30 (L) Hours

UNIT I

Dark Matter Evidences: Coma Cluster, Galaxy rotation curves, Halo models, Gravitational Lensing, Bullet Cluster, Massive, Astrophysical Compact Halo Objects (MACHOs), Cosmological: Cosmic Microwave Background Radiation, Big Bang Nucleosynthesis (BBN), Large scale structure formation, Baryon acoustic oscillation (BAO)

(10 Lectures)

UNIT II

Dark Matter candidates: WIMP miracle, sterile neutrinos, Axions, Supersymmetric candidates, Particles from extra dimensions, Wimpzillas, Primordial black holes, Searches for WIMPs: Direct detection of dark matter, Collider searches of dark matter Indirect detection of dark matter. Current experimental status (review).

(10 Lectures)

UNIT III

Direct detection of WIMP: Signal Rate of WIMP, Velocity Distribution, Correction: , Nuclear Form Factor, Detector response corrections, quenching factor, Spin-independent ('coherent') interactions, Spin-dependent interactions, Annual modulation.

(10 Lectures)

References

1. Dark Matter: An Introduction , Debasish Majumdar , CRC Press; 1 edition (2014)
2. Review of mathematics, numerical factors, and corrections for Dark Matter experiments based on elastic nuclear recoil. J. D. Lewin , P. F. Smith , Particle Physics Department, Rutherford Appleton Laboratory Chilton, Didcot, Oxon, OX11 0QX, UK (1996)
3. Particle Dark Matter: Observations, Models and Searches, edited by Gianfranco Bertone, Cambridge University Press.
4. Dark Matter: A Primer, Katherine Garrett and Gintaras Duda, (https://www.hindawi.com/journals/aa/2011/968283/).
5. Dark Matter, http://pdg.lbl.gov/2019/reviews/rpp2019-rev-dark-matter.pdf

CENTRAL UNIVERSITY OF SOUTH BIHAR

Master of Science (M.Sc.) Physics Programme

Syllabus

(Effective from Academic Session 2021-2022)

Department of Physics

SCHOOL OF PHYSICAL AND CHEMICAL SCIENCES

Two Years M.Sc. in Physics
Semester Wise Course Structure
(Total 80 Credits for Two Year M.Sc.)

Course Code	Course Title	Credit	
	Semester-I	**C**	**L/T/P**
MSPHY1001C04	Mathematical Physics-1	4	4/0/0
MSPHY1002C04	Quantum Mechanics	4	4/0/0
MSPHY1003C04	General Physics Lab. – I	4	0/0/4
MSPHY1004E04	Classical Mechanics	4	4/0/0
MSPHY1005E04	Nuclear and Particle Physics-I	4	4/0/0
MSPHY1006E04	Solid State Physics	4	4/0/0
MSPHY1007E04	Elective – I (From other department)/ Swayam Course*	4	4/0/0
MSPHY1008E04	Elective-II (From Elective Bucket)	4	4/0/0
	Total Credit	**32**	
	Semester - II	**L**	**T** **P**
Course Code	**Course Title**	**Credit**	
MSPHY2001C04	Classical Electrodynamics and Relativity	4	4/0/0
MSPHY2002C04	Statistical Mechanics	4	4/0/0
MSPHY2003C04	General Physics Lab. – II	4	0/0/4
MSPHY2004E04	Mathematical Physics-II	4	4/0/0
MSPHY2005E04	Atomic and Molecular Physics	4	4/0/0
MSPHY2006E04	Elective – III (From other department)/ Swayam Course*	4	4/0/0
MSPHY2007E04	Elective-IV (From Elective Bucket)	4	4/0/0
	Total Credit	**28**	
	Semester-III (Specialization in Condensed Matter Physics)	**L**	**T** **P**
Course Code	**Course Title**	**Credit**	
MSPHY3001C04	Advance Quantum Mechanics	4	4/0/0
MSPHY3002C04	Crystallography, Imperfection in Crystals & Diffraction Techniques	4	4/0/0
MSPHY3003C04	Condense Matter Physics Lab – I	4	0/0/4
MSPHY3004E04	Electronics and Experimental Methods	4	4/0/0
MSPHY3005E04	Experimental Techniques for Material Science	4	4/0/0

MSPHY3006E04	Computational Techniques for Solid State Physics	4	4/0/0	
MSPHY3007E04	Dissertation	4	4/0/0	
MSPHY3008E04	Elective-V (From Elective Bucket)	4	4/0/0	
Total Credit		**32**		
Semester-IV (Specialization in Condensed Matter Physics)		**L**	**T**	**P**
Course Code	**Course Title**	**Credit**		
MSPHY4001C04	Condensed Matter Physics	4	4/0/0	
MSPHY4002C04	Solid State Devices	4	4/0/0	
MSPHY4003C04	Condensed Matter Physics Lab – II	4	0/0/4	
MSPHY4004E04	Physics at Nano-Scale	4	4/0/0	
MSPHY4005E04	Physics of Magnetism and Spintronics	4	4/0/0	
MSPHY4006E04	Material Science	4	4/0/0	
MSPHY4007E04	Dissertation	4	4/0/0	
MSPHY4008E04	Elective-VI (From Elective Bucket)	4	4/0/0	
Total Credit		**32**		
Semester-III (Specialization in Nuclear and Particle Physics)		**L**	**T**	**P**
Course Code	**Course Title**	**Credit**		
MSPHY3001C04	Advance Quantum Mechanics	4	4/0/0	
MSPHY3102C04	Nuclear Physics-II	4	4/0/0	
MSPHY3103C04	Nuclear & Particle Physics Lab. – I	4	0/0/4	
MSPHY3004E04	Electronics and Experimental Methods	4	4/0/0	
MSPHY3105E04	Atrso-Particle Physics	4	4/0/0	
MSPHY3106E04	Dissertation	4	4/0/0	
MSPHY3107E04	Elective-VII (From Elective Bucket)	4	4/0/0	
Total Credit		**28**		
Semester - IV (Specialization in Nuclear and Particle Physics)		**L**	**T**	**P**
Course Code	**Course Title**	**Credit**		
MSPHY4101C04	Advanced Particle Physics	4	4/0/0	
MSPHY4102C04	Nuclear & Particle Physics Lab. – I	4	0/0/4	
MSPHY4103C04	Experimental techniques in Nuclear and Particle Physics	4	4/0/0	
MSPHY4104E04	Neutrino and Dark Matter Physics	4	4/0/0	
MSPHY4105E04	Particle Accelerator Physics	4	4/0/0	

MSPHY4106E04	Dissertation	4	4/0/0
MSPHY4107E04	Elective-VIII (From Elective Bucket)	4	4/0/0
	Total Credit	**28**	

Elective Bucket

Sr. No.	Course Code	Course Name
1.	MSPHY1E04	Elements of Ancient Indian Sciences
2.	MSPHY2E04	Biography of Indian Scientists
3.	MSPHY3E04	A Course on Ancient Indian Sciences
4.	MSPHY4E02	Physics of Dielectic and Ferroelectric Materials
5.	MSPHY5E04	Crystal Growth and Characterizations
6.	MSPHY6E04	Fundamentals of nanoscience and nanotechnology
7.	MSPHY7E02	X-ray Spectroscopy
8.	MSPHY8E02	Diffusion in Solids
9.	MSPHY9E04	Fundamentals of Scanning Probe Microscopy
10.	MSPHY10E04	Alloy Design and Development
11.	MSPHY11E04	Material Synthesis and Processing
12.	MSPHY12E04	Renewable Energy : Solar and Hydrogen
13.	MSPHY13E04	Nanostructres and Their Properties
14.	MSPHY14E04	Biomedical Instrumentation
15.	MSPHY15E04	Industrial Process Control
16.	MSPHY16E04	Nanoelectronics
17.	MSPHY17E04	Statistical Analysis Techniques in Nuclear and Particle Physics
18.	MSPHY18E04	Introduction of Astrophysics
19.	MSPHY19E04	Nuclear Reactor Physics
20.	MSPHY20E04	Data Analysis and Simulation in particle Physics
21.	MSPHY21E02	Radiation Safety

***The department will suggest a few courses from Swayam based on availability of Physics related courses at the portal.**

Course Title: Mathematical Physics-I

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY1001C04
Credits	:	4	**Course Title**	:	Mathematical Physics-I
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Linear vector spaces and operators: Vector spaces and subspaces, Linear dependence andindependence, Inner product, Orthogonality, linear operators, Matrix representation, Similarity transformations, Characteristic polynomial of a matrix, Eigen values and eigenvectors, Self adjoint and Unitary transformations, Eigen values and eigenvectors of Hermitian and Unitary transformations, diagonalization.

(20 Lectures)

Unit-2

Vector analysis and curvilinear co-ordinates: Gradient, Divergence and Curl operations,Vector Integration, Gauss' and Stokes' theorems, Curvilinear co-ordinates, Gradient, Curl, divergence and Laplacian in spherical polar and cylindrical polar co-ordinates. Definition of tensors, contravariant and covariant components of tensors.

(20 Lectures)

Unit-3

Ordinary differential equations and Special Functions: Linear ordinary differentialequations, Series solutions – Frobenius'method, Series solutions of the differentialequations of Bessel, Legendre, Leguerre and Hermite polynomials.

(20 Lectures)

References

1. Mathematical Methods of Physics - J. Mathews and R. L. Walker, Second Edition, Addison-Wesley.
2. Mathematical Methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012
3. Matrices and Tensors in Physics - M. R. Spiegel, Schaum Series
4. Linear Algebra – Seymour Lipschutz, Schaum Outlines Series
5. Matrices and Tensors in Physics - A.W. Joshi, Wiley Eastern Ltd, 1975
6. Vector Analysis - M. R. Spiegel, Schaum Series
7. Introduction to Dynamics – I. Percival and D. Richards, Cambridge University Press.

Course Title: Quantum Mechanics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY1002C04
Credits	:	4	**Course Title**	:	Quantum Mechanics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Wave mechanics: Schrodinger equation, Stationary states, one-dimensional potentials (infinite square well, finite square well, Delta-function potential, Harmonic Oscillator), Scattering in one-dimension

(20 % Weightage)

Unit-2

The Mathematics of quantum mechanics Linear vector spaces, Linear operators, Matrix representation of operators, Eigenvalues and Eigenvectors, Inner products, Linear functional , Adjoint operators, Hermitian and Unitary operators, Dirac notation, Uncertainty principle and compatible operators, Complete set of commuting operators.

(20 % Weightage)

Unit-3

Quantum Dynamics: Pictures in Quantum Mechanics: Schrodinger and Heisenberg pictures, Coherent and Squeezed states, spin precession in magnetic field, two-state system Identical particles: Exchange degeneracy, Symmetrization Postulate, Constructing symmetric and antisymmetric states, system of identical non-interacting particles, the Pauli's exclusion principle and the Periodic table

(20 % Weightage)

Unit-4

Angular Momentum and Spin, Tensor product states, Angular momentum Algebra of angular momentum, Central potential Hamiltonian (free particle, infinite spherical well, three-dimensional isotropic oscillator, hydrogen atom), Addition of Angular Momentum with applications in spin-orbit coupling and hyperfine splitting in hydrogen atom.

(20 % Weightage)

Unit-5

Approximation methods Time-independent perturbation theory for non- degenerate and degenerate levels, Application to ground state of an harmonic oscillator and Stark effect in Hydrogen, Variation method, Application to ground state of Helium atom,WKB approximation, WKB quantization rules, Applications in the theory of alpha-decay and field emission of electrons. (20 % Weightage)

References

1. Griffiths, David J. Introduction to Quantum Mechanics. Pearson Prentice Hall, 2004.
2. Zettile, Nouredine. Quantum Mechanics: Concepts and Applications, Wiley
3. Sakurai , J. J. Modern Quantum Mechanics. Cambridge University Press; 2nd edition
4. Shankar ,R. Principles of Quantum Mechanic. Springer
5. Cohen-Tannoudji, et al. Quantum Mechanics, Vols. 1 & 2. Wiley,

Course Title: General Physics Lab – 1

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY1003C04
Credits	:	4	**Course Title**	:	General Physics Lab – 1
L+T+P	:	0+0+4	**Contact Hours**	:	120 (P)

1. To study Hydrogen spectrum and determine Rydberg's constant with the help of spectrometer diffraction grating and a Hydrogen spectrum tube.
2. To determine wavelength of sodium light by Fresnel's Biprism method.
3. To determine specific rotation of sugar using polarimeter.
4. To measure radius of curvature of a Plano-convex lens using Newton's ring apparatus.
5. Determination of wavelength of sodium light using Newton's ring apparatus.
6. To determine wavelength of sodium light by diffraction grating using spectrometer.
7. To verify Norton's Theorem and to find equivalent current source circuit.
8. To verify Theivenin's theorem and to find equivalent voltage source circuit.
9. To verify superposition and maximum power transfer theorem.
10. To study transient response in R-C circuit.
11. Measurement of frequency and phase using Lissajous figure.
12. To study applications of operational amplifier as adder, substractor and buffer.
13. Construction and verification of Up / Down, synchronous/ asynchronous, ripple decade counters and 4 bits universal shift register.
14. To measure the charge to mass ratio (e/m) of the electron.
15. To find speed of sound using resonance column.
16. To study and construct different type of holographic photographs.
17. To verify Faraday and Lenz's law of induction by measuring the induced voltage as function of time.
18. To determine the speed of light in air.

- Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Classical Mechanics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY1004C04
Credits	:	4	**Course Title**	:	Classical Mechanics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Foundation: System of particles. Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalised co-ordinates, virtual displacement, D'Alembert's principle, Non-uniqueness of the Lagrangian, Simple applications of the Lagrangian formulation: 1. Single free particle in (a) Cartesian co-ordinates, (b) plane polar co-ordinates; 2. Atwood's machine; 3.bead sliding on a uniformly rotating wire in a force-free space; 4. Motion of block attached to a spring ; 5. Simple pendulum. Symmetries ofspace time: Cyclic coordinate, Conservation of linear momentum, angular momentum and energy. Variational Principle: Hamilton's Principle, Derivation of E-L equations, Extension to non-holonomic systems.

(15 Lectures)

Unit-2

Application: Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, equations of motion for the orbit, classification of orbits, the Kepler problem (inverse square law force). Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering. Motion in non-central reference frames: Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, the Foucault pendulum. Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia, classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body. Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula.

(15 Lectures)

Unit-3

Generalisation: Hamiltonian formulation: Generalised momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Examples of (a) the Hamiltonian of a particle in a central force field, (b) the simple harmonic oscillator, cyclic co-ordinates and conservation theorems, derivation of Hamilton's equations from variational principle. Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton- Jacobi method.

(15 Lectures)

References

1. Classical mechanics, H. Goldstein, C. Poole, J. Saflco, 3rd edition, Pearson Education Inc. (2002).
2. Classical mechanics, K. N. Srinivasa Rao, University Press (2003).
3. Classical mechanics, N. C. Rana and P. S. Joag, Tata McGraw-Hill (1991).
4. Classical dynamics of particles and systems, J. B. Marian, Academic Press (1970)

5. Introduction to classical mechanics, Takwale and Puranik, Tata McGraw-Hill (1983).
6. Classical mechanics, L. D. Landau and E. M. Lifshitz, 4th edition, Pergamon press (1985).

Course Title: Nuclear Physics-1

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY1005C04
Credits	:	42	**Course Title**	:	Nuclear Physics-1
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Nuclear forces: Characteristics of nuclear forces, Two nucleon system, Deuteron problem, binding energy, Ground State of the deuteron in square well potential, relation between the range and depth of the potential, magnetic moment and quadrupole moment of thedeuteron, deuteron ground state as an admixture of s and d states.

(10 Lectures)

Unit-2

Nuclear models : Shell model: Evidence for magic numbers, prediction of energy levels in aninfinite square well potential, spin-orbit interaction, prediction of ground state spin, parity of nucleus Liquid drop model, Weizsacker's Semi-empirical mass or binding energy formula. Collective models of the Nucleus.

(10 Lectures)

Unit-3

Radioactive Decay: Elementary ideas of alpha, beta and gamma decays and their selection rules. Fermi decay theory, Fission and fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions.

(10 Lectures)

Unit-4

Nuclear reactions: Type of nuclear reaction, quantities conserved in a nuclear reaction, kinematics of nuclear reaction, artificial transmutation elements, determination of Q-value of reaction, Nuclear reactions, reaction mechanism, compound nuclei and direct reactions.

(10 Lectures)

Unit-5

Particle Physics : Review of types of interaction in nature-typical strengths and time-scales, laws of conservation: charge-conjugation, parity and time reversal, CPT theorem and its implications, GellMann-Nishijima formula, intrinsic parity of pions, resonances, symmetry classification of elementary particles, quark hypothesis, charm, beauty and truth, gluons, quark confinement, asymptotic freedom. (20 Lectures)

References

1. Introduction to Nuclear Physics, Kenneth Krane, Wiley India Pvt. Ltd.
2. Introduction to Nuclear Physics, H. A. Enge, Eddison Wesley
3. Nuclei and Particle, E. Segre, W. A Benjamin,
4. Concepts of Nuclear Physics, B. L. Cohen
5. Nuclear Physics, Experimental and Theoritical, H. S. Hans, New Age International
6. Introduction to Nuclear and Particle Physics, A. Das & T. Ferbel, World Scientific
7. Nuclear and Particle Physics, W. E. Burcham and M. Jobes, Addison Wesley

8. Nuclear Physics, S. N. Ghoshal, Nuclear Physics-D. C. Tayal

9. Nuclear Physics-An Introduction, S. B. Patel, New Age International

Course Title: Soild State Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY1006C04
Credits	:	4	**Course Title**	:	SOLID STATE PHYSICS
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Structure and Symmetry: The basis and crystal structure, primitive and non-primitive lattice cell-fundamental types of lattice, -2d and 3-d Bravias lattice and crystal systems. Elements of symmetry operations points and space groups-nomenclature of crystal directions, Direct periodic lattices, Quasicrystals, Superfluidity. Ordered-phases of matter: translational and orientational order, kinds of liquid crystalline order.

(20 Lecture)

Unit-2

Free electron theory of metals :Free electron model, the density of states, Fermi-Dirac statistics, effect of temperature on Fermi distribution function, the electronic specific heat. Electrical conductivity of metals, relaxation time and mean free path, electrical conductivity, Wiedemann - Franz law, thermionic emission, Elementary ideas of quantum Hall effect, Cyclotron resonance and magnetoresistance. Band theory of solids: Band theory of solids: metals, insulators, number of states in a band, Energy gap.

(20 Lecture)

Unit-3

Magnetism: Free electron model, Pauli paramagnetic, Spontaneously spin-split bands, Landau levels, Landau diamagnetism, Magnetism of the electron gas, Spin density waves, Kondo effect, The Hubbard model. Magnetic anisotropy: Magnetic frustration, Spin glasses, Superparamagnetic. Superconductors: Critical temperature-persistent current-occurrence of super conductivity, ideal and non-ideal superconductors-Destruction of super conductivity by magnetic field - Meissner effect- heat capacity-energy gap-microwave and infrared properties-Isotope effect- BCS theory (qualitative)-Josephson tunneling-exotic superconductors- high Tc super conductors.

(20 Lecture)

References

1. Solid State Physics- A. J. Dekker.
2. Solid State Physics- C. Kittel.
3. Elementary Solid state physics,- M.A. Omar.
4. Introduction of Solids: L.V. Azaroff.
5. Solid State Physics: N.W. Ashcroft and N.D. Mermin.
6. Crystallography Applied to Solid State Physics: A.R. Verma and O.N. Srivastava
7. Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, CengageLearning
8. Solid-state Physics, H. Ibach and H. Luth, 2009, Springer
9. Elementary Dislocation Theory: Weertman and Weertman.

Course Title: Classical Electrodynamics and Relativity

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY2001C04
Credits	:	4	**Course Title**	:	Classical Electrodynamics and Relativity
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Electrostatics: Coulomb's law, Electric field, Gauss's law, applications of Gauss's law, Electric Potential, Poisson's equation and Laplace's equation, Work and energy in electrostatics, Techniques for calculating potentials: Laplace's equation in one, two and three dimensions, boundary conditions and uniqueness theorems, Method of Images, Multipole expansion Electrostatic fields in matter: Dielectrics, Polarization, Field inside a dielectric, Electric displacement, Linear dielectrics.

(9 Lectures)

Unit-2

Magnetostatics : Lorentz Force law, Biot-Savart Law, Divergence and Curl of B, Ampere's law and applications of Ampere's law, Magnetic vector potential, Multipole expansion. Magnetostatic fields in Matter: Magnetization, field of a magnetized object, magnetic field inside matter, linear and non linear magnetic media

(9 Lectures)

Unit-3

Electrodynamics: Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations. Scalar and vector potentials, gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials.Energy and momentum in electrodynamics.

(9 Lectures)

Unit-4

Electromagnetic waves : Electromagnetic waves in non conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reflection and transmission at interfaces. Fresnel's laws, interference, coherence transmission line and wave guides; Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion: Dispersion in non conductors, free electrons in conductors and plasmas. Guided waves.

(12 Lectures)

Unit-5

Electromagnetic Radiation : Retarded potentials, Electric dipole radiation, magnetic dipole radiation. Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion, Power radiated by a point charge.

(9 Lectures)

Unit-6

Relativity : Electrodynamics and Relativity: Review of special theory of relativity, Lorentz transformations, Minkowski four vectors, energy-momentum four vector, covariant formulation of mechanics Transformation of electric and magnetic fields under Lorentz transformations, field tensor, invariants of electromagnetic field, Covariant formulation of electrodynamics, Lorentz force on a relativistic charged particle.

(12 Lectures)

References

1. Introduction to Electrodynamics – David J. Griffiths, Fourth Edition, Pearson, 2013.
2. Classical Electrodynamics – J.D. Jackson, Fourth Edition, John Wiley & Sons, 2005.
3. Classical Electromagnetic Radiation – M.A. Heald and J.B. Marion, Saunders, 1983.

Course Title: Statistical Mechanics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY2002C04
Credits	:	4	**Course Title**	:	Statistical Mechanics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Classical statistical mechanics: Basic postulates of statistical mechanics, Macro-and micro states – Statistical equilibrium– Phase space, Ensemble: micro-canonical, canonical, grand canonical; Density function -– Liouville's theorem, Canonical distribution function: Evaluation of mean values in a canonical ensemble, Partition function– connection with thermodynamics; Statistical definition of entropy—Boltzmann equation and its significance; Ideal monoatomic gas, Gibbs' paradox, Equipartition theorem, specific heat of solids.

(15 Lectures)

Unit-2

Quantum statistical mechanics: Basic concepts – Quantum ideal gas, Identical particles and symmetry requirements, Quantum distribution functions, Bose-Einstein statistics, Ideal Bose gas, black body radiation, Bose-Einstein condensation, specific heat, Fermi-Dirac statistics, Ideal Fermi gas, properties of simple metals, Pauli paramagnetism, electronic specific heat, Quantum statistics in the classical limit.

(15 Lectures)

Unit-3

Irreversible processes and fluctuations: Random walk in one dimension, Brownian motion, Langevin equation, Fluctuation dissipation theorem, Einstein relation, Fourier analysis of random functions, Wiener-Khintchine relations Nyquist's theorem, Fluctuations and Onsager relations.

(15 Lectures)

References

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
2. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
3. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill.
4. Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall.
5. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
6. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
7. An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press.
8. Statistical Mechanics, K. Huang.
9. B. B. Laud, Fundamentals of Statistical Mechanics, New Age International Publication (2003).

Course Title: General Physics Lab – II

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY2003C04
Credits	:	4	**Course Title**	:	General Physics Lab – II
L+T+P	:	4+0+0	**Contact Hours**	:	120 (P)

1. To observe the dependence of the high frequency response of the analog link on D.C. Current passing through the photo transmitter.
2. To determine Bohr magneton and specific charge (e/m) of electron using Zeeman apparatus.
3. To determine Verdet's constant from the relation between rotation angle and magnetic flux using Faraday Effect apparatus.
4. To determine wavelength of laser using Michelson interferometer.
5. To study drain and transfer characteristics of JFET.
6. To study drain and transfer characteristics of MOSFET.
7. To study input, output and transfer characteristics of PNP / NPN transistor in CB mode.
8. To study input, output and transfer characteristics of PNP / NPN transistor in CE mode.
9. Application of IC- 555 as Pulse Generator Sequential Timer and pulse with modulator.
10. Construction and verification of half adder, full adder, half substractor, and full substractor using combinational circuits.
11. To construct and study JK, JKMS and T Flip flops.
12. Determination of ρ (rho) the resistance per unit length of a Carey Foster's bridge and find the melting point of given substance using Platinum resistance thermometer.
13. To study NAND gate as universal gate.
14. To study and verify binary storage counter, type t Flip – Flop, Up, Down and Decimal counter.
15. Construction and verification of Up / Down, synchronous/ asynchronous, ripple decade counters and 4 bits universal shift register.
16. Construction of Divide -by- N counters (6 or 60) using IC-7493 & IC-7490.

- Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Advanced Mathematical Physics-II

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY2004E04
Credits	:	4	**Course Title**	:	Advanced Mathematical Physics-II
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Fourier and Laplace transforms: Fourier Series, Fourier transform, Convolution theorem, Parseval's theorem, Laplace transform and its properties, convolution theorem, inverse Laplace transforms, solution of differential equations using Laplace transforms, Fourier transform & Laplace transform of Dirac Delta function.

(40 Lectures)

Unit-2

Complex analysis and Group theory: Functions of a complex variable, Analytic functions, Cauchy- Riemann relations, Cauchy's theorem, Cauchy's integral formula, Taylor and Laurent expansions, residue theorem, Evaluation of definite integrals, elementary idea of group theory.

(20 Lectures)

References

1. Mathematical methods of physics - J. Mathews and R. L. Walker, Second Edition, Addison- Wesley.
2. Mathematical methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012.
3. Complex functions – M. R. Spiegel, Schaum Series.
4. Mathematical Physics - P.K.Chattopadhyay, Wiley Eastern Ltd.1990.
5. Linear Algebra and Group theory for Physicists – K. N. Srinivasa Rao.

Course Title: Atomic and Molecular Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY2005E04
Credits	:	4	**Course Title**	:	Atomic and Molecular Physics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Atomic Structure and Atomic Spectra: One Electron Atom: Vector model of a one electron atom, Quantum states of an electron in an atom, Hydrogen atom spectrum, Spin-orbit coupling, Relativistic corrections for energy levels of hydrogen atom, Hydrogen fine structure, Spectroscopic terms, Hyperfine structure and isotopic shift.

(15 Lectures)

Unit-2

Two valance Electron Atom: Vector model for two valance electrons atom, LS coupling, Pauli exclusion principle, Interaction energy for LS coupling, Lande interval rule, JJ coupling, interaction energy for JJ coupling. Inner shell vacancy, X-rays and Auger transitions. chemical shift. Frank-Condon principle. Atom in Magnetic Field: Zeeman effect, Magnetic moment of a bound electron, Magnetic interaction energy in weak field. Paschen-Back effect, Magnetic interaction energy in strong field.

(15 Lectures)

Unit-3

Molecular Structure and Molecular Spectra :Types of molecules, Electronic, rotational, vibrational and Raman spectra of diatomic molecules, selection rules. Born-Oppenheimer approximation. Morse potential energy curve, Molecules as vibrating rotator, Vibration spectrum of diatomic molecule, PQR branches. Elementary discussion of Raman, ESR and NMR spectroscopy, chemical shift.

(15 Lectures)

Unit-4

Infrared spectroscopy: The vibrating diatomic molecule. The diatomic vibrating-rotator spectra of diatomic molecules Raman Spectroscopy: Introduction, Pure rotational Raman spectra, Vibrational Raman Spectra, Nuclear Spin and intensity alternation in Raman spectra, Isotope effect, Raman Spectrometer.

(15 Lectures)

References

1. Concepts of Modern Physics by Arthur Beiser (McGraw-Hill Book Company, 1987).
2. Atomic spectra & atomic structure, Gerhard Hertzberg: Dover publication, New York.
3. Molecular structure & spectroscopy, G. Aruldhas; Prentice – Hall of India, New Delhi.
4. Fundamentals of molecular spectroscopy, Colin N. Banwell& Elaine M. McCash, Tata McGraw –Hill publishing company limited.
5. Introduction to Atomic spectra by H.E. White,
6. Spectra of diatomic molecules by Gerhard Herzberg

Course Title: Advanced Quantum Mechanics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3001C04
Credits	:	4	**Course Title**	:	Advanced Quantum Mechanics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1: Scattering Theory

Kinematics of Scattering Process: differential and total cross-section -Asymptotic from of scattering wave function. Scattering amplitude by Green's method. Born approximation method and screened potential and square well potential as examples - Partial wave analysis and phase shift-Optical Theorem- Relationship between phase shift and Potential. Scattering by Hard sphere.

(20 % Weightage)

Unit-2: Time Dependent Perturbation Theory

Time dependent perturbation theory, Constant and harmonic perturbations,Transition probabilities,Fermi's-Golden rule,Semi classical treatment of an atom with electromagnetic radiation, Selection rules for dipole radiation, Adiabatic approximation, Sudden approximation

(20 % Weightage)

Unit-3: Many Electron Atom and Molecules

Constants of motion in central field approximation-Corrections to the central field approximation. Self consistent methods, Thomas-Fermi model,Hartee – Fock method, Born-Oppenheimer method, Molecular orbital theory, Valance bond theory, H2+ ion, Hydrogen molecule.

(20 % Weightage)

Unit-4: Relativistic Quantum Mechanic

Klein –Gordon Equation, Plane wave solution and Equation of continuity, Probability density- Dirac Equation, alpha, beta- matrices, Plane wave solution, significance of negative energy states. Spin of Dirac particle Relativistic particle in central potential –Total Angular Moment, Particle in a magnetic field – Spin Magnetic moment, properties of gamma matrices- Dirac's equation in covariant form. (20 % Weightage)

Unit-5: Field Quantization

Lagrangian density and equation of motion for field, Symmetries and conservation laws, Noether's theorem, cononical quantization of scalar field, Complex scalar field, electromagnetic field and Dirac field, Problem in quanitizing electromagnetic field, Gupta & Bleuler method, Feynman rules (without derivation), Feynman diagrams.

(20 % Weightage)

References

1. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
2. Quantum Mechanics Concepts and Applications- NouredineZettile, Second Edison, John Wiley and Sons. 2009
3. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
4. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
5. Relativistic Quantum Mechanics: J.D. Bjorken and S.D. Drell.

6. A First Book on Quantum Field Theory: AmitabhaLahiri and P.B. Pal.
7. An Introduction to Quantum Field Theory: M. E. Peskin and V. Schroeder; Persues Book
8. Introduction to QFT: F. Mandle and G. Shaw
9. Advance Quantum Mechanics- J. J. Sakurai

Course Title: Crystallography, Imperfection in Crystals and Diffraction in Crystals and Diffraction Techniques

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3002C04
Credits	:	4	**Course Title**	:	CRY., IMP. IN CRYS. & DIFF. TECHN.
L+T+P	:	3+1+0	**Contact Hours**	:	45 (L) + '15(T)

Unit-1

Close packing of spheres. Structure of common metals, alloys, ionic, covalent and molecular crystals, concepts of space group, symmetries, and its relevance to crystal structure. General procedure for working out the details of space groups with illustrations from triclinic, monoclinic and orthorhombic systems. Wyckoff positions. Principles of crystal structure analysis. Structure factor calculations, Space group extinctions. Electron density functions. Phase problem. Patterson functions.

Unit-2

Production and properties of x-rays: Continuous and characteristic spectrum. Principle of Powder diffractometer, Interaction of x-rays with matter.Laue equations.Bragg's law. Reciprocal lattice concept and its applications to rotation, Powder diffractometry. Application of powder method, Determination of relative structure amplitudes from measured intensity (Lorentz and Polarization factors), Direct methods in crystallography. Debye Scherrer, Guinier and Bragg-Brentano geometries for powder diffractometers. General intensity expression for powder diffraction. Rietveld refinement technique. Quantitative phase analysis and microstructure determination. Limitations of powder method. Single crystal diffractometers. Indexing of electron diffraction patterns

Unit-3

Mechanism of plastic deformation in solids, Stress and strain fields of screw and edge dislocations, Elastic energy of dislocations, Forces between dislocations, Stress needed to operate Frank-Read source, Dislocations in fcc, hcp and bcc lattices, Partial dislocations and stacking faults in close packed structures. Experimental method of detecting dislocations and stacking faults, Electron Microscopy: Kinematical theory of diffraction contrast and lattice imaging.

References

1. Crystallography for Solid State Physics: Verma and Srivastava.
2. X-ray Crystallography: Azarof.
3. Elementary Dislocation Theory: Weertman and Weertman.
4. Crystal Structure Analysis: Buerge.
5. Electron Microscopy of Thin Crystals: Hirsh.
6. X-ray Diffraction B.D. Culty
7. B.E.Warren – X-ray Diffraction.
8. O. Madelung – Introduction of Solid State Theory (Springer).
9. J.M. Ziman: Principles of the theory of solids

Course Title: Condensed Matter Physics Lab-1

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3003C04
Credits	:	4	**Course Title**	:	Condensed Matter Physics Lab-1
L+T+P	:	0+0+4	**Contact Hours**	:	120 (P)

1. To study the relationship between temperature of given samples (1&2) and its time of cooling by plotting a cooling curve and identify the samples.
2. To study Hall Effect in semiconductor and determine Hall coefficient (Rh) & charge career density. Characterization of Nano-fluids like Ag/Au & ferrofluids.
3. To evaluate modest nano-particles concentrations in the fluid for significant enhancement of its property.
4. Study of phase transition and to detect/assess weak and strong molecular interactions in nano-fluids.
5. To determine the Stefan's constant by using an incandescent lamp and Photovoltaic cell.
6. To demonstrate Hysteresis curve of hard magnet.
7. To determine Dielectric constant of specimen at high frequency by Lecher wires.
8. To study the dispersion relation for mono-atomic lattice and determine the cut of frequency.
9. To determine heat capacity of solids
10. Measurement of Planck's constant using LED.
11. Measurement of Planck's constant using photo voltaic cell
12. Phase problem and determination of crystal structures.
13. Indexing of X-Ray powder diffraction patterns.
14. Atomic scattering factor and structure factor determination.
15. Experimental determination of space group and inversion symmetry.
16. Refinement procedures

- Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Electronics and Experimental Methods

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3004E04
Credits	:	4	**Course Title**	:	Electronics and Experimental Methods
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1: Operational amplifiers

Block diagram of an operational amplifier – Characteristics of an ideal operational amplifier – comparison with 741 – Operational amplifier as a open loop amplifier - Limitations of open loop configuration – Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain. Applications of op-amp: Linear applications – Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier – inverting and non-inverting configurations, subtractor, difference summing amplifier, ideal and practical Differentiator, Integrator. Non – linear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers. basic comparator, zero-crossing detector, Schmitt trigger, Oscillators

(20 Lectures)

Unit-2: Digital techniques

Boolean laws and theorems, simplification of SOP equations, Simplification ofPOS equations, Simplification using Karnaugh Map technique (4 variables)- conversion of binary to Greycode. Flip flops: Latch using NAND and NOR gates- RS flip flop, clocked RS flip flop, JK flip flop, JKmaster slave flip flop - racing –Shift Registers basics - Counters: Ripple counters truth table-timingdiagram, Synchronous counters-truth table-timing diagram, Decade counter. Visual displays:Single-element displays, seven-segment displays, decoder logic. Digital to Analog converters: ladder andweighted resistor types. Analog to digital Converters-counter method, successive approximation and dualslope converter. Application of DAC and ADCand applications

(15 Lectures)

Unit-3: Microprocessor

The ideal microprocessor, architecture of microprocessor, organisation ofmicroprocessor, features of Intel 8085, 8085 functional pin description, 8085 CPUarchitecture, microcontroller basics.

(5 Lectures)

Unit-4: Data interpretation and analysis

Precision and accuracy. Error analysis, propagation of errors. Least squares fitting, Linear and nonlinear curve fitting, chi-square test. Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Measurement and control. Signal conditioning and recovery. Impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding. Fourier transforms, lock-in detector, box-car integrator, modulation techniques. High frequency devices (including generators and detectors).

(25 Lectures)

References

1. Op-Amps and Linear Integrated Circuits, Ramakant A Gayakwad, (Third Edition, 2004), Eastern Economy Edition.

2. Operational Amplifiers with Linear Integrated Circuits, William Stanley, (1988), CBS Publishers and Distributors.

3. Linear Integrated Circuits, D Roy Choudhury and Shail Jain, ((1991), New Age International (P) Limited.

4. Digital principles and applications, Donald P Leach and Albert Paul Malvino, (Fifth Edition, 2002), Tata McGraw Hill.
5. Digital systems, Principles and applications, Ronald J Tocci and Neal S Widmer, (Eighth Edition, 2001), Pearson Education. Physics of Semiconductor Devices, Shur, PHI P
6. Microprocessor Architecture Programming & Applications – R.S. Gaonkar.
7. Microprocessor 8085: Architecture, Programming, & Interfacing – A. Wadhwa
8. Bevington P. and Robinson D. K. "Data Reduction and Error Analysis for the Physical Sciences", 2002, 3rd edition, ISBN-13: 978-0072472271
9. Bohm G. Zech, G. "Introduction to Statistics and Data Analysis for Physicists", http://www-library.desy.de/preparch/books/vstatmpengl.pdf
10. John E. Freund's "Mathematical Statistics with Applications", 2012, 8th edition, ISBN-13:978-0321807090
11. Feigelson, E. Babu, J. "Modern Statistical Methods for Astronomy: With R Applications", 2012, ISBN-13: 978-0521767279

Course Title: Experimental Techniques for Material Science

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3005C04
Credits	:	4	**Course Title**	:	Expt. Techn. for Mat. Sci.
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Vacuum Techniques: Introduction, flow regimes (Knudsen's number, Reynold's number, turbulent, laminar, viscous, molecular), different ranges of vacuum (low, medium, high), pumps (rotary, diffusion, turbo molecular), pressure gauges (pirani, penning, ion). Digital Instruments: Principle and working of digital meters, comparison of analog & digital instruments, characteristics of a digital meter.

(15 Lectures)

Unit-2

Optical Microscopy; Scanning Electron Microscopy; Scanning Tunneling Microscopy; Atomic Force Microscopy; X-ray diffraction, Neutron diffraction

(15 Lectures)

Unit-3

Transmission Electron Microscopy; Low Energy Electron Diffraction; Reflection of High Energy Electron Diffraction; Electron Spectroscopy for chemical analysis; Auger Electron spectroscopy; Secondary ion mass spectroscopy; Electron Energy Loss Spectroscopy, Molecular spectroscopies including Microwave, FTIR, Raman and surface enhanced Raman Spectroscopy. (15 Lectures)

Unit-4

X-ray Fluorescence; Rutherford back scattering; UV-VIS-NIR spectro-photometer, Ellipsometry; Deep Level Transient Spectroscopy; Thermally Simulated Current; C-V and Admittance Spectroscopy; Hall effect and Time of Flight methods for charge carriers, Differential scanning calorimeter; Differential Thermal Analyzer. (15 Lectures)

References

1. Sayer, M., Mansingh, A., Measurement, Instrumentation and Experiment Design in Physics and Engineering, PHI (2000).

2. Nanotechnology-Molecularly Designed Materials : G.M. Chow & K.E. Gonsalves (American Chemical Society), 1996.

3. Nanoparticles and Nanostructured Films–Preparation, characterization and Application : J.H. Fendler (Wiley), 1998

Course Title: Computational Techniques for Solid State Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3006C04
Credits	:	4	**Course Title**	:	Comput. Techni. for Solid State Phys.
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1: Basic computer programming

Flow chart, FORTRAN programming preliminaries, FORTRANconstants & variables

(15 Lectures)

Unit-2: Arithmetic expression

I/O statements, control statements (Do, if, while loop), formatspecification, logical expression, Function/subroutines, File processing, Examples

(15 Lectures)

Unit-3: Nuemricals Methods

Methods for determination of Zeroes of linear and nonlinear algebraic equations andtranscendental equations, convergence of solutions. Solution of simultaneous linear equations,Gaussian elimination, pivoting, iterative Method, Matrix inversion.

(15 Lectures)

Unit-4: Matrices

Eigen values and eigenvectors of matrices, power and Jacobi method Finite Differences,interpolation with equally spaced and unevenly spaced point, Curve fitting Polynomial leastsquares, Numerical solution of ordinary differential equation, Euler & Runga-Kutta method,Numerical integration, Trapezoidal rule, Simpson's method.

(15 Lectures)

References

1. Sastry : Introductory methods of Numerical Analysis
2. Rajaraman : Numerical Analysis and Fortran Programming
3. Gupta S.K. (1995) Numerical Methods for Engineers, NewAge International.
4. Chapra S.C. and Canale R.P. (2006) Numerical Methodsfor Engineers, 5th Ed; McGraw Hill.

Course Title: Condensed Matter Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4001C04
Credits	:	4	**Course Title**	:	Condensed Matter Physics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

UNIT-1

Ewald's method, Lorentz field, Phonons in perfect-crystals: General theory of latticedynamics of non-primitive lattice, normal coordinate description, quantization of latticevibrations, phonon concept, ionic crystals, shell model. Inelastic scattering of slow neutrons by crystals for study of phonons.Kramer-Kronig relation.

UNIT-2

Dielectric constant of ionic crystals, Static polarizability, polarizability in variable field, placzek's approximation, first order Raman scattering, second-order Raman scattering, elementary ideas of the study of phonons by Raman scattering Plasmons, interaction of electromagnetic waves with phonons and polaritons.

UNIT-3

Magnetism: Classical and Semi Classical Theories: Failure to explain large internal fields.Exchange interaction. Ising Model. Bragg William Approximation.Explanation of largeexternal fields. Non-existence of ferromagnetism in two-dimensional Ising Model. Two sublattice Model and classical theories of antiferromagnetic and ferrimagnetism, Ferrites andgarnets.

UNIT-4

Second Quantized Theory: Ferromagnetic Heisenberg Hamiltonian, HolsteinPrimakoff transformations and their application to Heisenberg Hamiltonian for smallfractional spin reversal. Ferromagnetic magnons, Magnon heat capacity and saturationmagnetization at small temperatures. Anti-ferromagnetic Hamiltonian and its reduction usingHolstein Primakoff transformation, Anti-ferromagnetic magnons.Zero point sub-latticemagnetization. The Magnetic Phase Transition: Order parameter, Landau's theory of secondorder phase Transitions. Fluctuations of the order parameter. Elementary qualitative ideasabout critical exponents and scaling.

References

1. Solid State Physics- A. J. Dekker.
2. Solid State Physics- C. Kittel.
3. B.E.Warren – X-ray Diffraction.
4. Maradudin – Solid State Physics (Supplement 3) (Academic Press).
5. O. Madelung – Introduction of Solid State Theory (Springer).
6. J.M. Ziman: Principles of the theory of solids
7. Solid State Physics: Mattis
8. Electron Paramagnetic Resonance: Pake
9. Molecular spectroscopy: Banwell.

Course Title: Solid State Devices

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4002C04
Credits	:	4	**Course Title**	:	Solid State Devices
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Classification of Semiconductors; Crystal structure with examples of Si, Ge & GaAs semiconductors; Energy band structure of Si, Ge & GaAs; Extrinsic and compensated Semiconductors; Temperature dependence of Fermi-energy and carrier concentration. Drift, diffusion and injection of carriers; Carrier generation and recombination processes- Direct recombination, Indirect recombination, Surface recombination, Auger recombination; Applications of continuity Equation-Steady state injection from one side, Minority carriers at surface, Haynes Shockley experiment, High field effects. Hall effect; Four – point probe resistivity measurement; Carrier life time measurement by light pulse technique. Introduction to amorphous semiconductors, Growth of semiconductor crystals.

(18 Lectures)

Unit-2

Fabrication of p-n junction by diffusion and ion-implantation; Abrupt and linearly graded junctions; Thermal equilibrium conditions; Depletion regions; Depletion capacitance, Capacitance – voltage (C-V) characteristics, Evaluation of impurity distribution, Varactor; Ideal and Practical Current-voltage (I-V) characteristics; Tunneling and avalanche reverse junction break down mechanisms; Minority carrier storage, diffusion capacitance, transient behavior; Ideality factor and carrier concentration measurements; Carrier life time measurement by reverse recovery of junction diode; p-i-n diode; Tunnel diode, Introduction to p-n junction solar cell and semiconductor laser diode.

(18 Lectures)

Unit-3

Schottky barrier – Energy band relation, Capacitance- voltage (C-V) characteristics, Current-voltage (I-V) characteristics; Ideality factor, Barrier height and carrier concentration measurements; Ohmic contacts. Bipolar Junction Transistor (BJT): Static Characteristics; Frequency Response and Switching. Semiconductor heterojunctions, Heterojunction bipolar transistors

(10 Lectures)

Unit-4

Junction Field Effect Transistor (JFET) - Construction, Characteristic parameters, Transfer Characteristics, applications; Introduction to ideal MOS device; MOSFET fundamentals, Measurement of mobility, channel conductance etc. from Ids vs Vds and Ids vs Vg characteristics; Metal-semiconductor field effect transistor (MESFET)- Device structure, Principles of operation, Current voltage (I-V) characteristics, High frequency performance.

(14 Lectures)

References

1. S.M. Sze; Semiconductor Devices: Physics and Technology, 2nd edition, John Wiley, New York, 2002.
2. B.G. Streetman and S. Benerjee; Solid State Electronic Devices, 5th edition, Prentice Hall of India, NJ, 2000.
3. W.R. Runyan; Semiconductor Measurements and Instrumentation, McGraw Hill, Tokyo, 1975.

4. Adir Bar-Lev: Semiconductors and Electronic devices, 2nd edition, Prentice Hall, 1984.

5. Donald A. Neamen; Semiconductor Physics and Devices: Basic Principles, 3rd edition, Tata McGraw-Hill, New Delhi, 2002.

6. M. Shur; Physics of Semiconductor Devices, Prentice Hall of India, New Delhi, 1995.

Course Title: Condensed Matter Physics Lab – II

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4003C04
Credits	:	4	**Course Title**	:	Condensed Matter Physics Lab – II
L+T+P	:	0+0+4	**Contact Hours**	:	120 (P)

1. To study characteristics of a solar cell.
2. To measure the charge Q on a plate capacitor as a function of the applied voltage E.
3. To determine the capacitance C as a function of areas A of plates.
4. To determine the capacitance C with different dielectrics between the plates.
5. To determine the capacitance C as a function of the distances d between the plates.
6. To determine resistivity of a given semiconductor by Four probe.
7. To draw the characteristics of a P-N junction diode for reverse saturation current and temperature.
8. To determine the Band gap in a semiconductor using a junction diode.
9. To study Hall effect in semiconductor and determine Hall coefficient (Rh), mobility ,Hall angle tan (θ) & conductivity .
10. Crystallographic measurements using XRD.

- Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Physics at Nano-Scale

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4004E04
Credits	:	4	**Course Title**	:	Physics at Nano-Scale
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Introduction to nanophysics and nanotechnology – scaling laws and limits to smallness; quantum nature of nanoworld; quantum confinement, density of states.

(20 % Weightage)

Unit-2

Nano fabrication (top-down and bottom-up process) andNanoscopy (electron microscopy, atomic force microscopy, scanning tunnelingmicroscopy)

(20 % Weightage)

Unit-3

Properties and application of dielectric and metal nanostructures – individual nanoparticles and nanoclusters; nanostructured materials; carbonnanostructures;nanomagnets.

(20 % Weightage)

Unit-4

Properties and application of semiconductor nanostructures - fabrication of semiconductor nanowires and quantum dots; electronic and optical properties (2D and 3D quantum confinement) quantum dots, nanowire- and quantum-dot-based electronic and photonic devices. (20% Weightage)

References

1. E.L. Wolf, (2004) Nanophysics and nanotechnology: An introduction to modern concepts innanoscience Wiley-VCH

2. Ch. Poole Jr., F. J. Owens, (2003) Introduction to nanotechnology John Wiley & Sons

Course Title: Physics of Magnetism & Spintronics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4005E04
Credits	:	4	**Course Title**	:	Physics of Magnetism & Spintronics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

UNI-1

Magnetism in metals: Free electron model, Pauli paramagnetic, Spontaneously spin-split bands, Landau levels, Landau diamagnetism, Magnetism of the electron gas, Excitations in the electron gas, Spin density waves, Kondo effect, The Hubbard model. Magnetic anisotropy: Shape anisotropy, Magneto-crystalline anisotropy and its origin, Induced anisotropy Competing interactions and low dimensionality: Magnetic frustration, Spin glasses, Superparamagnetic, One and two-dimensional magnets, Spin chain, Spin-Peierl's transition, Spin ladders

(15 Lectures)

UNIT-2

Introduction- overview of development of Spintronics and its future scope, Magnetic multilayers, Magnetic Anisotropy of thin films, Interlayer Exchange Coupling and Exchange Bias, Spin dependent transport - Anisotropic magnetoresistance, Giant Magneto Resistance (GMR) effect - Phenomenological theory, Microscopic theory for current in plane (CIP) and current perpendicular to plane (CPP) GMR, Effects of spin-flip scattering Spin tunneling, Tunnel Magnetoresistance (TMR), Effects of Fermi surface, Effect of interfacial states, diffusive tunneling, Spin flip tunneling, Bias voltage dependence of TMR, Magnetic tunnel Junctions (MTJ), Tunnel Junctions with Half Metals

(15 Lectures)

UNIT-3

Introduction to thin films, Technology as a drive and vice versa, Basics of vacuum science and technology, Vacuum pumps and gauges. Physical vapor deposition, Raoult's law of evaporation, evaporation rate, evaporation of elements, compounds and alloys, Hertz Knudsen equation; Knudsen cell, Film Thickness Uniformity and Purity

(15 Lectures)

UNIT-4

Molecular beam epitaxy (effusion cell, growth rate, growth of GaAs/AlGAs and GSMBE), Role of Kinetics of Adsorption and Desorption, Surface reconstruction, In-situ film characterization of MBE films by LEED and RHEED, & RHEED Oscillations, Pulsed Laser deposition (PLD process steps, congruent evaporation, advantages and disadvantages of PLD). CVD advantages, CVD Reaction types, Thermodynamics of CVD, Gas Transport, Viscous flow, Close-Spaced Vapor Transport (CSVT), Convection, Film Growth Kinetics, Axial and radial film thickness uniformity, Classification of CVD systems, APCVD, LPCVD & MOCVD and Examples of CVD growth.

(15 Lectures)

References

1. S. Blundell, Magnetism in Condensed Matter, 1st edition, Oxford University Press, 2001.
2. R. C. O' Handley, Modern Magnetic Materials, John Wiley & Sons, Inc., 2000.
3. T. Shinjo (Ed.) Nanomagnetism and Spintronics, 1st edition, Elsevier, 2009.
4. E. Y. Tsymbal and I Zutic, Handbook of Spin Transport and Magnetism, CRC Press, 2012.
5. Materials Science of Thin Films Deposition and Structure, Milton Ohring.

6. Thin Film Solar Cells, Chopra and Das
7. Thin Film Deposition: Principles and Practice, Donald Smith.
8. Handbook of Thin Film Deposition (Materials and Processing Technology), Krishna Seshan.

Course Title: Materials Science

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4006C04
Credits	:	4	**Course Title**	:	Materials Science
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Formation and structure of materials: Introduction to Materials Science- Engineering materials - structure - property relationship, Review of ionic, covalent and molecular bindings, bond angle, bond length and bond energy, lattice energy - Madelung constant cohesive energy, van der Waal's Interaction- Lennard- Jones Potential, closed packed structure-packing efficiency and density of materials. Crystal imperfections: Review of crystalline imperfection, Schottky and Frenkel defects- Equilibrium concentrations, edge and screw dislocations, surface imperfections.

Unit-2

Elastics and plastics behavior of materials: Atomic model of elastic behavior-rubber like Elasticity- anelastic behavior, viscoelastic behavior, fracture of materials-Ductile and brittle fracture – Ductile brittle transition, protection against fracture Plastic deformation by slip-shear strength of perfect and real crystals- CRSS ratio, maximum stress to move dislocation, methods of strengthening crystalline materials against plastic deformation-strain hardening, grain refinement, solid solution strengthening, precipitation strengthening.

Unit-3

Composite materials: Classification of composite materials, matrix materials- polymer, metals, ceramics, reinforcing materials- fibers, particles, concrete-concrete making materials, structure, composition, properties and applications, polymer-concrete composites, fabrication, structure, application of polymer matrix composites, metal matrix composites, ceramic-matrix composites, carbon-fibre composites, fibre reinforce, particle reinforce composites with properties and applications.

Unit-4

Elements of polymer science: Monomers- Polymers- classification polymers, synthesis of polymers-chain polymerization, step polymerization, Industrial polymerization methods, Average molecular weight- weight, number & viscosity, size of polymer molecule. Microstructure of polymers- chemical, geometric, random, alternating and block polymers. Phase transition-Polymer melting and glass transition, stereo isomerism, degree of crystallinity. Process of plastic materials: Moulding- compression, injection, blow, extrusion, spinning.

References

1. Elements of Materials Science and Engineering: Lowrence H. Van Vlack, Addison Wesley, (1975).
2. Introduction to Ceramics: W D Kingery, H K Bower and VR'uhlman, John Wiley, (1960)
3. Foundations of Materials Science and Engineering-William F. Smith, McGraw Hills International Edition, (1986)
4. Materials Science and Engineering, V. Ragharan, Prentice Hall (1993)
5. Structure & Properties of materials-vol I-IV Rose, Shepard and Wulff (1987)
6. Polymer Science, V. R Gowariker, N.V. Vishwanathan, JoydevShreedhar, Wiley Eastern (1987)

Course Title: Advanced Quantum Mechanics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3001C04
Credits	:	4	**Course Title**	:	Advanced Quantum Mechanics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1: Scattering Theory

Kinematics of Scattering Process: differential and total cross-section -Asymptotic from of scattering wave function. Scattering amplitude by Green's method. Born approximation method and screened potential and square well potential as examples - Partial wave analysis and phase shift-Optical Theorem- Relationship between phase shift and Potential. Scattering by Hard sphere.

(20 % Weightage)

Unit-2: Time Dependent Perturbation Theory

Time dependent perturbation theory, Constant and harmonic perturbations,Transition probabilities,Fermi's-Golden rule,Semi classical treatment of an atom with electromagnetic radiation, Selection rules for dipole radiation, Adiabatic approximation, Sudden approximation

(20 % Weightage)

Unit-3: Many Electron Atom and Molecules

Constants of motion in central field approximation-Corrections to the central field approximation. Self consistent methods, Thomas-Fermi model,Hartee – Fock method, Born-Oppenheimer method, Molecular orbital theory, Valance bond theory, H2+ ion, Hydrogen molecule.

(20 % Weightage)

Unit-4: Relativistic Quantum Mechanic

Klein –Gordon Equation, Plane wave solution and Equation of continuity, Probability density- Dirac Equation, alpha, beta- matrices, Plane wave solution, significance of negative energy states. Spin of Dirac particle Relativistic particle in central potential –Total Angular Moment, Particle in a magnetic field – Spin Magnetic moment, properties of gamma matrices- Dirac's equation in covariant form. (20 % Weightage)

Unit-5: Field Quantization

Lagrangian density and equation of motion for field, Symmetries and conservation laws, Noether's theorem, cononical quantization of scalar field, Complex scalar field, electromagnetic field and Dirac field, Problem in quanitizing electromagnetic field, Gupta & Bleuler method, Feynman rules (without derivation), Feynman diagrams.

(20 % Weightage)

References

1. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
2. Quantum Mechanics Concepts and Applications- NouredineZettile, Second Edison, John Wiley and Sons. 2009
3. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
4. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
5. Relativistic Quantum Mechanics: J.D. Bjorken and S.D. Drell.

6. A First Book on Quantum Field Theory: AmitabhaLahiri and P.B. Pal.
7. An Introduction to Quantum Field Theory: M. E. Peskin and V. Schroeder; Persues Book
8. Introduction to QFT: F. Mandle and G. Shaw
9. Advance Quantum Mechanics- J. J. Sakurai

Course Title: Nuclear Physics-II

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3102C04
Credits	:	4	**Course Title**	:	Nuclear Physics-II
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Nucleon-Nucleon Interaction: Two nucleon scattering, n-p scattering, partial wave analysis, phase-shift, scattering length, p-p scattering (qualitative discussion), charge symmetry and charge independence of nuclear forces. Exchange nature of nuclear forces and tensor forces, experimental evidence for the tensor force, elementary discussion on Yukawa's theory.

(15 lectures)

Unit-2

Beta and Gamma decay : Fermi's theory of beta decay, allowed and forbidden transitions, selection rules, non-conservation of parity in beta decay, electron capture, direct evidence for the neutrino, gamma–decay and selection rules, Internal Conversion, Resonant absorption- the Mossbaur effect.

(15 lectures)

Unit-3

Nuclear Reaction : Direct reaction mechanism, validation of shell model, photo-nuclear reaction, Coulomb excitation, fission, mass distribution of fragments, cross section for fission, Energy distribution, Isomeric fission, complete and incomplete fusion of heavy ions, Breit-Wigner one-level formula, stripping and pick up reactions, optical model to nuclear reaction, Scattering matrix, Neutron Spectroscopy: classification, sources of neutron, detection,

(15 lectures)

Unit-4

Nuclear Reactor: Self sustained reaction, four factor formula, reactor theory, critical size, reactor materials, reactor control, breeder reactor, thermonuclear fusion, fusion in plasma, fission reactor, conditions for sustained fusion, magnetic confinement, toroidal confinement: Tokomak.

(15 lectures)

References

1. Introduction to Nuclear Physics, Kenneth Krane, Wiley India Pvt. Ltd.
2. Introduction to Nuclear Physics, H. A. Enge, Eddison Wesley
3. Nuclei and Particle, E. Segre, W. A Benjamin,
4. Concepts of Nuclear Physics, B. L. Cohen
5. Nuclear Physics, Experimental and Theoritical, H. S. Hans, New Age International
6. Introduction to Nuclear and Particle Physics, A. Das & T. Ferbel, World Scientific
7. Nuclear and Particle Physics, W. E. Burcham and M. Jobes, Addison Wesley
8. Nuclear Physics, S. N. Ghoshal, Nuclear Physics-D. C. Tayal
9. Nuclear Physics-An Introduction, S. B. Patel, New Age International

Course Title: Nuclear and Particle Physics Lab. – I

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3103C04
Credits	:	4	**Course Title**	:	Nuclear and Particle Physics Lab. – I
L+T+P	:	0+0+4	**Contact Hours**	:	120 (P)

1. Study of the characteristics of a GM tube and determination of its operating voltage and plateau length.
2. Verify the inverse square relationship between the distance and intensity of radiation using GM Counter.
3. Detecting low level radioactivity in food.
4. Geiger Counter Experiment: Detecting alpha, beta and gamma radiation
5. Geiger Counter Experiment: Counting Statistics
6. Study of energy resolution characteristics of a scintillation spectrometer as a function of applied high voltage and to determine the best operating voltage.
7. Study of Cs-137 spectrum and calculation of FWHM and resolution for a given scintillation detector.
8. Study of Co-60 spectrum and calculation of resolution of detector in terms of energy.
9. Setup the coincidence circuit in the a cosmic muon test bench
10. Variation of energy resolution with gamma energy

*Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Electronics and Experimental Methods

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3004E04
Credits	:	4	**Course Title**	:	Electronics and Experimental Methods
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1: Operational amplifiers

Block diagram of an operational amplifier – Characteristics of an ideal operational amplifier – comparison with 741 – Operational amplifier as a open loop amplifier - Limitations of open loop configuration – Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain. Applications of op-amp: Linear applications – Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier – inverting and non-inverting configurations, subtractor, difference summing amplifier, ideal and practical Differentiator, Integrator. Non – linear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers. basic comparator, zero-crossing detector, Schmitt trigger, Oscillators

(20 Lectures)

Unit-2: Digital techniques

Boolean laws and theorems, simplification of SOP equations, Simplification ofPOS equations, Simplification using Karnaugh Map technique (4 variables)- conversion of binary to Greycode. Flip flops: Latch using NAND and NOR gates- RS flip flop, clocked RS flip flop, JK flip flop, JKmaster slave flip flop - racing –Shift Registers basics - Counters: Ripple counters truth table-timingdiagram, Synchronous counters-truth table-timing diagram, Decade counter. Visual displays:Single-element displays, seven-segment displays, decoder logic. Digital to Analog converters: ladder andweighted resistor types. Analog to digital Converters-counter method, successive approximation and dualslope converter. Application of DAC and ADCand applications

(15 Lectures)

Unit-3: Microprocessor

The ideal microprocessor, architecture of microprocessor, organisation ofmicroprocessor, features of Intel 8085, 8085 functional pin description, 8085 CPUarchitecture, microcontroller basics.

(5 Lectures)

Unit-4: Data interpretation and analysis

Precision and accuracy. Error analysis, propagation of errors. Least squares fitting, Linear and nonlinear curve fitting, chi-square test. Transducers (temperature, pressure/vacuum, magnetic fields, vibration, optical, and particle detectors). Measurement and control. Signal conditioning and recovery. Impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding. Fourier transforms, lock-in detector, box-car integrator, modulation techniques. High frequency devices (including generators and detectors).

(25 Lectures)

References

1. Op-Amps and Linear Integrated Circuits, Ramakant A Gayakwad, (Third Edition, 2004), Eastern Economy Edition.

2. Operational Amplifiers with Linear Integrated Circuits, William Stanley, (1988), CBS Publishers and Distributors.

3. Linear Integrated Circuits, D Roy Choudhury and Shail Jain, ((1991), New Age International (P) Limited.

4. Digital principles and applications, Donald P Leach and Albert Paul Malvino, (Fifth Edition, 2002), Tata McGraw Hill.

5. Digital systems, Principles and applications, Ronald J Tocci and Neal S Widmer, (Eighth Edition, 2001), Pearson Education. Physics of Semiconductor Devices, Shur, PHI P

6. Microprocessor Architecture Programming & Applications – R.S. Gaonkar.

7. Microprocessor 8085: Architecture, Programming, & Interfacing – A. Wadhwa

8. Bevington P. and Robinson D. K. "Data Reduction and Error Analysis for the Physical Sciences", 2002, 3rd edition, ISBN-13: 978-0072472271

9. Bohm G. Zech, G. "Introduction to Statistics and Data Analysis for Physicists", http://www-library.desy.de/preparch/books/vstatmpengl.pdf

10. John E. Freund's "Mathematical Statistics with Applications", 2012, 8th edition, ISBN-13:978-0321807090

11. Feigelson, E. Babu, J. "Modern Statistical Methods for Astronomy: With R Applications", 2012, ISBN-13: 978-0521767279

Course Title: Astroparticle Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3105E04
Credits	:	4	**Course Title**	:	Astroparticle Physics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Review of Astrophysics: The Milky way, radiation and energy density, cosmic abundance of the elements, the galactic magnetic field, Nucleosynthesis, supernova, white dwarfs, neutron dwarfs, pulsars, black hole, synchrotron radiation, Galactic Radiation: charged component of Primary Cosmic rays, neutrino astronomy, Gamma astronomy, X-ray astronomy, gravitational-wave astronomy.

(15 Lectures)

Unit-2

The Birth of Cosmic Ray: Stellar evolution, the pp chain, Supernova explosions, Supernova neutrinos, Supernova remnants, Acceleration of cosmic rays: Cyclotron mechanism, stochastic acceleration of charged particles Fermi mechanism, acceleration with energy loss, energy spectra,

(15 Lectures)

Unit-3

Cosmic Ray Interaction : Strong, electromagnetic and weak interaction and weak interactions, Units of energy and interaction, Electromagnetic process in matter: Coulomb scattering, Ionization loss, Cherenkov light, Compton scattering, Bremsstrahlung, creation of electron-positron scattering, Synchrotron radiation, Inverse Compton effect, kinematics variables and invariant cross-section.

(15 Lectures)

Unit-4

Ultra High Energy Cosmic Ray (UHECR) :Cosmic microwave background, UHECR interactions on the microwave background, Propagation of UHE protons and nuclei, Possible astrophysical sources of UHECR, GZK cutoff, current status of the field, High energy neutrino and gamma-ray astronomy (review).

(15 Lectures)

References

1. High Energy Cosmic Rays , Todorstanev, Springer
2. Cosmic Rays and Particle Physics, By Thomas K. Gaisser, Cambridge University Press.
3. High Energy Radiation from Black Holes: Gamma Rays, Cosmic Rays, and Neutrinos, By Charles D. Dermer, Charles Dermer, GovindMenon, Princeton University Press.
4. Ultra-high Energy Particle Astrophysics, By Shigeru Yoshida, Nova Science Publishers, Inc. New York.

Course Title: Advanced Particle Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4101C04
Credits	:	4	**Course Title**	:	Advanced Particle Physics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

A Preview of Particle Physics :Fundamental Building Blocks and their nature of Interactions, Classification of elementary particles by masses, Conservation Laws: Energy, Angular Momentum, electromagnetic Charge, Lepton flavor and Baryon Numbers. Natural units system, Relativistic kinematics.

(10 Lectrures)

Unit-2

Symmetries and Quarks :Symmetries in Physics, Symmetries and Groups (Brief Introduction), Group SU(2), Combining Representations, Finite Symmetry Groups: P and C, SU(2) of Isospin, Isospin for Antiparticles, Group SU(3), Example of an SU(3) Group: Isospin and Strangeness, Quark-Antiquark States : Mesons, Three-Quark States: Baryons, Magnetic Moments, Heavy Quarks: Charm and Beyond, Hadron Masses, Color Factors.

(10 Lectrures)

Unit-3

QUANTUM ELECTRODYNAMICS (QED) : Structure of the QED Lagrangian, gauge invariance and conserved current, scalar electrodynamics, Feynman rules for QED, phase space integration, Casimir's Trick and the Trace Theorems, Miller and Bhabha scattering, polarisation vectors, Compton scattering and pair creation/annihilation, Klein Nishina formula, Higher Orders in QED: Concept of multi-loop diagrams (no computation), momentum integral, UV and IR singularities, idea of regularisation, running coupling constant.

(10 Lectrures)

Unit-4

QUARK PARTON MODEL : Isospin and strangeness, introduction to unitary groups, generators, Casimir invariants, fundamental and adjoint representations, root and weight diagrams, meson and baryon octets, baryon decuplet, Gell-Mann-Nishijima formula. symmetry group, Young tableaux, quark model, Deep Inelastic Scattering, Elastic scattering off a point particle, Rosenbluth formula, Breit frame, inelastic scattering, structure functions, dimensionless variables. Bjorken scaling, parton model, structure functions in terms of PDFs, Callan-Gross relation, kinematic regions, valence and sea quarks, gluons.

(15 Lectures)

Unit-5

WEAK INTERACTIONS : Fermi theory of Beta decay, Fermi and Gamow-Teller transitions, current-current form of weak interactions, Fermi constant, universality, unitarity violation at high energies. Intermediate vector bosons, unitarity, requirement of conserved currents, muon decay, pion decay, Parity violation, experiments of Wu et al and of Goldhaber et al, maximal parity violation, CP Violation.

(15 Lectures)

References

1. Introduction to Elementary Particles by D. Griffiths (2nd Ed., Wiley-VCH, 2008).

2. Quarks and Leptons, by F. Halzen and A.D. Martin (Wiley 1984).

3. Particle Physics, by B.R. Martin and G. Shaw (Wiley 2008).
4. Elementary Particle Physics by S. Gasiorowicz (John Wiley, 1966)
5. Elementary Particles and the Laws of Physics by R. P. Feynman and S. Weinberg (Cambridge University Press, 1999)
6. Introduction to Elementary Particle Physics by A. Bettini (Cambridge University Press, 2008)

Course Title: Nuclear and Particle Physics Lab. – II

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4102C04
Credits	:	4	**Course Title**	:	Mathematical Physics-I
L+T+P	:	0+0+4	**Contact Hours**	:	120 (P)

1. Estimation of Efficiency of the G.M. detector for (a) Gamma source and (b) Beta Source.
2. Geiger Counter Experiment: Capturing and Dectecting Radon in the Environment
3. To Study Beta Particle Range and Maximum Energy (Feather Analysis)
4. Backscattering of Beta particles
5. Measurement of short half-life
6. Linear Absorption Coefficient
7. Energy calibration of Gamma Ray Spectrometer (Study of linearity)
8. Energy Analysis of an Unknown Gamma Source
9. Study the activity of a given Gamma Source using relative method.
10. Study the activity of a given Gamma Source using absolute Method.
11. Study the mass absorption coefficient for 662 keV gamma rays in lead
12. To study the absorption of gamma-radiation by different media like Lead, Aluminium, and Plastic.
13. Stuy the photoelectric absorption of photons and verify the strong dependence of this process on the atomic number of the absorbing material.
14. LabView: basic code
15. LabView: FPGA

- Any experiment can be added / deleted at any time during the course in / from the list of the experiments.

Course Title: Experimental Techniques in Nuclear and Particle Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4103C04
Credits	:	4	**Course Title**	:	Expt. Techn. in Nucl, and Part. Phys.
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Detection of radiations : Interaction of gamma-rays, electrons, heavy charged particles, neutrons, neutrinos and other particles with matter. General properties of Radiation detectors, energy resolution, detection efficiency and dead time. Statistics and treatment of experimental data. Gas-filled detectors, Proportional counters, space charge effects, energy resolution, time characteristics of signal pulse, position-sensitive proportional counters, Multiwire proportional chambers, Drift chamber, Time projection chamber. Organic and inorganic scintillators and their characteristics, light collection and coupling to photomultiplier tubes and photodiodes, description of electron and gamma ray spectrum from detector, phoswich detectors, Cherenkov detector. Semiconductor detectors, Ge and Si(Li) detectors, Charge production and collection processes, detector structures and fabrication aspects, semiconductor detectors in X- and gamma-ray spectroscopy, Pulse height spectrum, Compton-suppressed Ge detectors, Semiconductor detectors for charged particle spectroscopy and particle identification, Silicon strip detectors, Radiation damage. Electromagnetic and Hadron calorimeters. Motion of charged particles in magnetic field, Magnetic dipole and quadrupole lenses, beta ray spectrometer. Detection of fast and slow neutrons - nuclear reactions for neutron detection. General Background and detector shielding.

(20 Lectrures)

Unit-2

Electronics associated with detectors : Electronics for pulse signal processing, CR-(RC) n and delay-line pulse shaping, pole-zero cancellation, baseline shift and restoration, preamplifiers (voltage and charge-sensitive configurations), overload recovery and pileup, Linear amplifiers, single-channel analyser, anolog-to-digital converters, multichannel analyzer. Basic considerations in time measurements, Walk and jitter, Time pickoff methods, time-to-amplitude converters, Systems for fast timing, fast-slow coincidence, and particle identification, NIM, VMI and PXI instrumentation standards and data acquisition system.

(20 Lectures)

Unit-3

Experimental methods : Detector systems for heavy-ion reactions : Large gamma and charge particle detector arrays, multiplicity filters, electron spectrometer, heavy-ion reaction analysers, nuclear lifetime measurements (DSAM and RDM techniques), production of radioactive ion beams. Detector systems for high energy experiments : Collider physics (brief account), Particle Accelerators (brief account), Secondary beams, Beam transport, Modern Hybrid experiments-CMS and ALICE.

(20 Lectures)

References

1. Introduction to Experimental Particle Physics by Richard Fernow (Cambridge University Press), 2001.
2. Radiation detection and measurement by Glenn F. Knoll (Wiley), 2010.
3. Techniques in Nuclear and particle Experiments by W.R. Leo (Springer), 1994.
4. Detectors for particle radiation by Konrad Kleinknecht (Cambridge University Press), 1999.

Course Title: Neutrino and Dark Matter Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4104E04
Credits	:	4	**Course Title**	:	Neutrino and Dark Matter Physics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Important historical experiments : Birth of the neutrino, Nuclear recoil experiment by Rodeback and Allen, Discovery of the neutrino, solar neutrino detection parity violation in weak interactions, helicity of the neutrino, Discovery of weak neutral currents, Discovery of the weak gauge bosons W and Z Observation of neutrinos from SN 1987A, Number of neutrino flavours from the width of the Z bosons. Dirac and Majorana mass terms, Experimental status of lepton number violation.

(15 Lectrures)

Unit-2

Neutrino oscillations : General formalism, C P and T violation in neutrino oscillations, Oscillations with two neutrino flavours, The case for three flavours, Experimental considerations, Nuclear reactor experiments, Experimental status, Accelerator-based oscillation experiments: LSND, KARMEN, Future test of the LSND evidenceMiniBooNE Searches at higher neutrino energy: CHORUS and NOMAD Neutrino oscillations in matter, C P and T violation in matter, Possible future beams: Off-axis beams and experiments, Beta beams, Superbeams, Muon storage rings neutrino factories.

(15 Lectrures)

Unit-3

Dark Matter Evidences: Coma Cluster, Galaxy rotation curves, Halo models, Gravitational Lensing, Bullet Cluster, Massive, Astrophysical Compact Halo Objects (MACHOs), Cosmological: Cosmic Microwave Background Radiation, Big Bang Nucleosynthesis (BBN), Large scale structure formation, Baryon acoustic oscillation (BAO)

(15 Lectures)

Unit-4

Direct detection of WIMP: Signal Rate of WIMP, Velocity Distribution, Correction: , Nuclear Form Factor, Detector response corrections, quenching factor, Spin-independent ('coherent') interactions, Spin-dependent interactions, Annual modulation.

(15 Lectures)

References

1. K. Zuber, "Neutrino Physics", IoP Publishing 2004.
2. C. Giunti and C.W.Kim, "Fundamentals of Neutrino Physics and Astrophysics", Oxford University Press, 2007.
3. R. N. Mohaptara and P. B. Pal, "Massive Neutrinos in Physics and Astrophysics", World Scientific (2ndEdition), 1998
4. H.V. Klapdor-Kleingrothaus& K. Zuber, "Particle Astrophysics",IoP Publishing, 1997.
5. Scientific American articles:"Detecting Massive Neutrinos", E. Kearns, T. Kajita, Y. Totsuka, Scientific American, August 1999."Solving the Solar Neutrino Problem", A.B. McDonald, J.R. Klein, D.L. Wark, Scientific American, April 2003.

6. Dark Matter: An Introduction , DebasishMajumdar , CRC Press; 1 edition (2014)

7. Review of mathematics, numerical factors, and corrections for Dark Matter experiments based on elastic nuclear recoil. J. D. Lewin , P. F. Smith , Particle Physics Department, Rutherford Appleton Laboratory Chilton, Didcot, Oxon, OX11 0QX, UK (1996)

8. Particle Dark Matter: Observations, Models and Searches, edited by Gianfranco Bertone, Cambridge University Press.

9. Dark Matter: A Primer, Katherine Garrett andGintarasDuda, (https://www.hindawi.com/journals/aa/2011/968283/).

10. Dark Matter, http://pdg.lbl.gov/2019/reviews/rpp2019-rev-dark-matter.pdf

Course Title: Particle Accelerator Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY4105E04
Credits	:	4	**Course Title**	:	Particle Accelerator Physics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Charged Particle Dynamics : Particle motion in electric and magnetic fields, Beam transport system, Beam pulsing and bunching techniques, microbeams, Particle and ion sources, secondary beams, Measurement of beam parameters.

(10 Lectures)

Unit-2

Radiofrequency Accelerators : Linear accelerators - Resonance acceleration and phase stability, electron and proton Linacs. Circular accelerators- Cyclotron, Frequency Modulated Synchrocyclotron, AVF Cyclotron, Alternating-gradient accelerators.

(15 Lectures)

Unit-3

Electrostatic and Heavy Ion Accelerators : Van de Graaff voltage generator, Cockcroft-Walton voltage generator, insulating column, voltage measurement, Acceleration of heavy ions, Tandem electrostatic accelerator, Production of heavy negative ions, Pelletron and Tandetron, Cluster beams, Superconducting Heavy Ion Linear Accelerators.

(15 Lectures)

Unit-4

Synchrotron Radiation Sources : Electromagnetic radiation from relativistic electron beams, Electron synchrotron, dipole magnet, multipole wiggler, noncoherent and coherent, Undulator, Characteristics of synchrotron radiation.

(10 Lectures)

Unit-5

Radioactive ion beams : Production of Radioactive ion beams, Polarized beams, Proton synchrotron, Colliding accelerators. Applications : Use of accelerators and Ion-beam Analysis Techniques.

(10 Lectures)

References

1. Particle Accelerator Physics, Vol I and II, H.J. Wiedman, (Springer Verlag), 1998.
2. Particle Accelerators, M.S. Livingston and J.P. Blewel, (McGraw-Hill Book Press), 1962.
3. Nuclear Spectroscopy and Reactions Part-A, Ed. J. Cerny, (Academic Press), 1974.
4. Theory of Resonance Linear Accelerators by I.M. Kapchenkey, (Harwood Academic Publishers).

Course Title: Elements of Ancient Indian Sciences

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY1E04
Credits	:	4	**Course Title**	:	Elements of Ancient Indian Sciences
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Basic Concepts: Some essential definitions; The ultimate truth and the observable world; Expansion of self as the observable world; Classification of Indian Knowledge Systems; The objects of human pursuit; Fundamental basis for all Indian knowledge systems; The prescriptive nature of Indian discourses; The causal nature of universe; Means of acquiring knowledge; Prevalent social practice as source of knowledge - in view of modern statistical studies; Two way flow of knowledge; Vedas and Vedaangas; Indian Science and its evolution; Popularising Science among masses; Concept of cyclic time (25 Lectures)

Unit-2

Ancient Indian Mathematics and its similarities and contrast from modern mathematics; Ancient Indian Astronomy; Elements of modern physics in ancient indian sciences; The science of language; Sanskrit as world's most mathematical human language; Ayurveda - The science of well-being; Social and economic sciences; Science of preservation of knowledge (Indian Education System); Agricultural Sciences; Metallurgical Sciences; Computer Science; Civil Engineering; Architecture; Chemistry; Mechanical Engineering

(25 Lectures)

Unit-3

Other topics: Indian systems as a solution to environmental problems; Role and status of women in Indian systems; Dharma in the root of all Indian sciences; Comparative study of the oral and the scriptural traditions; Sanskrit for technical discourse; Falsification of word-to-word translation; HetvABHASa and and its relevance in policy making of Indian science; Discussion on modern concept of patent/copyright in view of ancient practices; Pandemics in ancient scientific literature; Human body as a prototype of social structure; Darshana in contrast to Philosophy

(10 Lectures)

References

1. Indian Science and Technology in the Eighteenth Century: Some Contemporary European Accounts - Dharampal; Other India Press
2. The History of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited
3. The golden age of Indian mathematics - S Parameswaran; Swadeshi Science Movement Kerala
4. Science in Samskrita; Samskrita Bharati
5. Pride of India: A glimpse into India's scientific heritage; Samskrita Bharati
6. The Wonder that is Sanskrit - Sampad & Vijay; Auro Publications

Course Title: Biography of Indian Scientists

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY2E04
Credits	:	4	**Course Title**	:	Biography of Indian Scientists
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1: Historical Accounts of Ancient Indian Scientists

Baudhaayana, Aaryabhata, Brahmagupta, Bhaaskaraachaarya, Mahaaviiraachaarya, Kanaad, Varaahamihira, Naagaarjuna, Sushruta, Charak, Vaagbhatta, Patanjali, PaNini, Chaanakya; Pingala, Lagaadha, Bharata Muni, Maadhava, Dhanvantari, Kapila Muni, Bhaaradwaj Muni.

(30 Lectures)

Unit-2: Biographical Sketch of Modern Indian Scientists

Sir J C Bose, Prafulla Chandra Roy, Srinivas Ramanujan, Sir C Venkata Raman, Meghnad Saha, S N Bose, Shanti Swarup Bhatnagar, Homi Jehangir Bhabha, S Chandrashekhar, Vikram Sarabhai, C R Rao, K V Chandrashekhar, Har Govind Khurana, G N Ramachandran, Harish Chandra, M K Vainu Bappu, M Visvesvaraya, Subhash Mukhopadhyay, Raja Ramanna, A P J Abdul Kalam, Vashishtha Narayan Singh

(30 Lectures)

References

1. Biography of Indian Scientist - A Chattopadhyay
2. Bharat Ke Mahan Vaigyanik Famous Indian Scientists And Their Biographies - Arvind Gupta
3. The golden age of Indian mathematics-S Parameswaran; Swadeshi Science Movement Kerala
4. The history of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited
5. Wings of Fire: An Autobiography - A P J Abdul Kalam with Arun Tiwari; University Press

Course Title: A Course on Ancient Indian Sciences

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY3E04
Credits	:	4	**Course Title**	:	A Course on Ancient Indian Sciences
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Revision of Basic Concepts

(5 Lectures)

Unit-2: Ancient Indian Mathematics

Definition of GaNita; Importance and all pervading nature of GaNita; Prescriptive nature of GaNita; Concept of zero; Decimal System; Arithmetics; Algebra; Negative numbers; Trigonometry; GaNita in Vedaangas; Early Geometry; Concept of π, $\sqrt{2}$, $\sqrt{3}$ etc.; Shulba-Sootra - Geometrical Calculations; GaNita Jyotisha; GaNita in prosody; GaNita in language; GaNita in music (Hemchandra Series); Binary system; Permutations and Combinations; Kerala school; Early Calculus; Upapatti - Indian version of proof; Similarities and contrast from modern mathematics

(10 Lectures)

Unit-3: Ancient Indian Astronomy

Jyotisha - the science of time-keeping; Importance of Jyotisha; GaNita Jyotisha; Panchaanga; Phalita Jyotisha; Phalita Jyotisha and the causal nature of universe; works of different ancient scientists in the field of Jyotisha

(5 Lectures)

Unit-3: Physics

Use of GaNita as prescription in contrast to use of mathematics as description; Motion; Gravitation; Concept of Paramaanu - Vaisheshik darshana; Syaatvaada and probabilistic interpretation of quantum mechanics; Cosmology; Causality; Physics in Jain and Bauddha darshana; HetvABHAsa and its relevance in policy making of Indian science

(10 Lectures)

Unit-4: The science of Language

Meaning of Bhasha; Evolution of language; Praakrita and Sanskrita; Grammar of Sanskrita - Ashtadhyaayii by Paaninii; Sanskrit as world's most mathematical human language; Sanskrit for technical discourse; Basic knowledge of Sanskrita (Dhaatu, Pratyaya, Vibhakti, Vachana, Linga, Purusha; Lakaara, Sandhi, Samaasa); Order of words in Sanskrita; Rules to make new words; Falsification of word- to-word translation; Language as vehicle of culture and civilisation; Science in Sanskrita literature

(10 Lectures)

Unit-4: The science of well-being

Definition of Ayurveda; Swaasthya in contrast to health; Importance of being healthy; Ayurveda as a way of life; Vaata, Pitta, Kapha; Quality of a good medicine; Yoga and Praanaayaama - definition and its importance as a method for well-being; Air, Water, Soil, Oil, Ghee, Cloth as a tool to heal; Mantra-healing; Surgery in ancient India; Healthy diet; Indian kitchen - a medicine store; Contribution of homemaking women in evolution of Ayurveda

(10 Lectures)

Unit-4: Social and Economic Sciences

Expansion of self as family; Human body as a prototype of social structure; Family as a prototype for social administration; Gandhi's idea of Swaraajya; Sharing as a way of life; Economic system based on sharing; Sanskaaras - Prescription for proper distribution; Jaati as an economical unit; Village as an independent economic unit; Arthashaastra; Concept of virtual money in today's world and its absence in ancient Indian economic systems; Evolution of modern economic system based on virtual money, banks and markets; Comparative study of modern economic system with the ancient one; The Angus Maddison report (10 Lectures)

References

1. Indian Science and Technology in the Eighteenth Century: Some Contemporary European Accounts - Dharampal; Other India Press
2. The History of ancient Indian mathematics - C N Srinivasiengar; The World Press Private Limited
3. The golden age of Indian mathematics - S Parameswaran; Swadeshi Science Movement Kerala
4. Science in Samskrita; Samskrita Bharati
5. Pride of India: A glimpse into India's scientific heritage; Samskrita Bharati
6. The Wonder that is Sanskrit - Sampad & Vijay; Auro Publications

Course Title: Physics of Dielectric and Ferroelectric Materials

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHYE04
Credits	:	2	**Course Title**	:	Phys. of Diele. & Ferroele. Mater.
L+T+P	:	2+0+0	**Contact Hours**	:	30 (L)

Unit-1

Introduction to Dielectrics: Polarisation mechanisms in dielectrics: induced, orientational, electronic, ionic, interfacial and lattice polarizations; combined mechanisms. Classical and quantum theory of polarization, Dielectric Relaxation mechanism, Applications of dielectrics Macroscopic electric field – Local electric field at an atom – Dielectric constant and polarizability – Clausius-Mossotti equation, The complex impedance method, calculations of permittivity and dielectric losses, cole-cole plots. Spontaneous polarization and ferroelectrics, Phase Transitions of the first and second order. Ferroelectric Liquid Crystals. Fundamental of piezoelectricity, Search method for ferroelectric and piezoelectric materials, Material processing for ferroelectric and piezoelectric materials, Characterization technique of piezoelectricity, Defect studies of ferroelectric and piezoelectric materials, Application of ferroelectric and piezoelectric materials.

(20 Lectures)

Unit-2

Case Studies:

1. Study of the ferroelectric properties of thin films by using sawyer tower circuit
2. Study of dielectric relaxation phenomena,
3. Study of the temperature dependence of permittivity in ferroelectrics
4. Study of the RLC circuit with nonlinear capacitor,
5. Determination of field-dependence of permittivity in ferroelectrics,
6. Study of the piezoelectric effect by the method of resonance impedance.

References

1. Gerald Burns, Solid State Physics, Academic Press, 1990.
2. Kwan Chi Kao, Dielectric Phenomena in Solids, Elsevier Academic Press (2004)
3. J.D. Livingston, Electronic Properties of Engineering Materials, Wiley, 1999
4. L.L. Hench and J.K. West, Principles of Electronic Ceramics, Wiley, 1990
5. J. Grindlay, An introduction to the phenomenological theory of ferroelectricity, Pergamon Press, Oxford, 1970
6. Karin M. Rabe, Charles H. Ahn, Jean-Marc TrisconePhysics of Ferroelectrics: A Modern Perspective, Springer (2007)

Course Title: Crystal Growth and Characterization

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY5E02
Credits	:	4	**Course Title**	:	Crystal Growth and Characterization
L+T+P	:	2+0+2	**Contact Hours**	:	30 (L) + 60(P)

Unit-1

Fundamentals of Crystal Growth: Importance of crystal growth – Classification of crystal growth methods – Basic steps: Generation, transport and adsorption of growth reactants – Nucleation: Kinds of nucleation –Classical theory of nucleation: Gibbs Thomson equations for vapour and solution – Kinetic theory of nucleation – Becker and Doring concept on nucleation rate – Energy of formation of a spherical nucleus – Statistical theory on nucleation: Equilibrium concentration of critical nuclei, Free energy of formation.

(10 Lectures)

Unit-2

Crystal Growth Techniques: Melt Growth : Basics of melt growth – Heat and mass transfer – Conservative growth processes: Bridgman-Stockbarger method – Czochralski pulling method – Kyropolous method – Nonconservative processes: Zone-refining – Vertical and horizontal float zone methods – Skull melting method – Vernueil flame fusion method. Solution Growth : Growth from low temperature solutions: Selection of solvents and solubility – Meir's solubility diagram – Saturation and supersaturation – Metastable zone width – Growth by restricted evaporation of solvent, slow cooling of solution and temperature gradient methods– Crystal growth in Gel media: Chemical reaction and solubility reduction methods – Growth from high temperature solutions: Flux growth Principles of flux method – Choice of flux – Growth by slow evaporation and slow cooling methods. Vapour Growth :Basic principles – Physical Vapour Doposition (PVD): Vapour phase crystallization in a closed system – Gas flow crystallization – Chemical Vapour Deposition (CVD): Advantageous and disadvantageous

(20 Lectures)

Practical :- Growth and Characterization

1. Growth of crystals
2. Characterization and analysis using
3. Single crystal X-Ray Diffraction
4. Powder X-Ray Diffraction,
5. FT-IR spectroscopy,
6. UV-Vis spectroscopy,
7. Raman Spectroscopy,
8. Dielectric, Non Linear
9. Optical (NLO) Studies

References

1. J.C. Brice, Crystal Growth Processes, John Wiley and Sons, New York, 1986,
2. J.W. Mullin, Crystallization, , Elsevier Butterworth-Heinemann, London, 2004
3. Ichiro Sunagawa, Crystals: Growth, Morphology and Perfection, Cambridge University Press, Cambridge, 2005.
4. B.R. Pamplin, Crystal Growth, Pergamon Press, Oxford, 1975
5. Characterization of Materials (Materials Science and Technology:A Comprehensive treatment,Vol 2A & 2B, VCH (1992).
6. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press (2008).
7. P.E. J. Flewitt and R K WildPhysical methods for Materials Characterization, , IOP Publishing (2003).

Course Title: Fundamental of Nanoscience and Nanotechnology

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY6E04
Credits	:	4	**Course Title**	:	Fund. of Nanosci. and Nanotechn.
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Metal nanoclusters: Magic numbers, Geometric Structure, Electronic Structure, Bulk-to-Nano transition; Semiconducting nanoparticles: Optical properties; Rare-gas and molecular clusters: Inert gas clusters, Superfluid clusters, Molecular clusters, Methods of synthesis: RF plasma, Chemical methods, Thermolysis, Pulsed-Laser method Cohesive Energy: Ionic solids, Defects in Ionic solids, Covalently bonded solids, Organic crystals, Inert-gas solids, Metals Quantum wells, wires and dots: Fabricating techniques for Quantum Nanostructures, effect of size and dimension on conduction electrons, Applications

(15 Lectures)

Unit-2

Vibrational Properties: The finite One-dimensional monoatomic lattice, Ionic solids, Experimental Observations: Optical and acoustical modes; Vibrational spectroscopy of surface layers of nanoparticles – Raman spectroscopy of surface layers, Infrared Spectroscopy of surface layers; Photon confinement, Effect of dimension on lattice vibrations, Effect of dimension on vibrational density of states, effect of size on Debye frequency, Melting temperature, Specific heat, Phase transitions. Electronic Properties: Effect of lattice parameter on electronic structure, Free electron model, The Tight-Binding model; Measurements of electronic structure of nanoparticles: Semiconducting nanoparticles, Organic solids, Metals.

(15 Lectures)

Unit-3

Mechanical Properties: Stress-Strain Behavior of materials; Failure Mechanism of Conventional Grain-Sized Materials; Mechanical Properties of Consolidated Nano-Grained Materials; Nanostructured Multilayers; Mechanical and Dynamical Properties of Nanosized Devices, Methods of Fabrication of Nanosized Devices.

(15 Lectures)

Unit-4

Magnetism in Nanostructures : Basics of Ferromagnetism; Behavior of Powders of Ferromagnetic Nanoparticles : Properties of a single Ferromagnetic Nanoparticles, Effect of nanosized grain structure on magnetic properties, Magnetoresisitive materials; Spintronics: Definition and examples of spintronic devices, Magnetic storage and spin valves, Dilute magnetic semiconductors; Molecular switches and electronics: Molecular switches, Molecular electronics, Mechanism of conduction through a molecule; Photonic crystals.

(15 Lectures)

References

1. The Physics and Chemistry of Nanosolids, Frank J. Owens and Charles P. Poole, Wiley- Interscience, 2008.

2. Frank J. Owens, Physics of Magnetic Nanostructures, Wiley- Interscience, 2015.

Course Title: X-Ray Spectroscopy

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY7E02
Credits	:	2	**Course Title**	:	X-Ray Spectroscopy
L+T+P	:	2+0+0	**Contact Hours**	:	30 (L)

UNIT I

Unit-1

Source of X-rays (classic and synchrotron radiation), Interaction of x-rays with matter (photoeffect, Compton effect, elastic scattering, Auger effect), Detectors for X-rays, Optical elements for X-rays (mirrors, monochromators, (micro)focusing elements) , X-ray diffraction, small angle scattering, X-ray fluorescence, X-ray absorption spectroscopy, Introduction to analysis of atomic and molecular structure with x-ray spectroscopic methods; Micro-spectroscopy (combination of XAS and micro focusing of SR X-ray beam) and 2D elemental mapping with sub-micron resolution, In-situ in in-operando spectroscopic techniques with X-rays (20 Lectures)

Unit-2

Photoemission Electron Microscopy - X-ray Absorption Spectroscopy - X-ray Magnetic Linear Dichroism (XMLD) - X-ray Magnetic Circular Dichroism (XMCD) - Temperature and angle dependence of X-ray Magnetic Dichroism. (10 Lectures)

References

1. G. Bunker, “Introduction to XAFS: A Practical Guide to X-ray Absorption Fine Structure Spectroscopy”, Cambridge University Press, 2010
2. X-ray absorption spectroscopy (principles, applications, techniques of EXAFS, SEXAFS and XANES), edited by D.C. Konnigsberger and R. Prins, John Wiley and Sons, NY (1988)
3. D. A. Skoog, F. J. Holler, T. A. Nieman, Principles of Instrumental analysis, Saunders Colege Publishing, Philadelpia, 1998

Course Title: Diffusion in Solids

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY8E02
Credits	:	2	**Course Title**	:	Diffusion in Solids
L+T+P	:	2+0+0	**Contact Hours**	:	30 (L)

Unit-1

Laws of diffusion. Solution of Fick's diffusion equation under simple boundary conditions. Types of diffusion. Diffusion and concentration gradient. Compositional dependence of diffusion. Diffusion in metals and alloys. (15 Lectures)

Unit-2

Methods of determining diffusion coefficients. Diffusion in ionic solids. Diffusion and conductivity. Point defects. Interaction of point defects. Analysis of typical binary compounds. Diffusion in ternary compounds, ferrites, oxides, sulfides, silicates etc. Diffusion and solid state reactions. (15 Lectures)

References

1. Elements of Materials Science and Engineering: Lowrence H. Van Vlack, Addison Wesley, (1975).
2. Introduction to Ceramics: W D Kingery, H K Bower and VR'uhlman, John Wiley, (1960)
3. Foundations of Materials Science and Engineering-William F. Smith, McGraw Hills
4. International Edition, (1986)
5. Materials Science and Engineering, V. Ragharan, Prentice Hall (1993)
6. Structure & Properties of materials-vol I-IV Rose, Shepard and Wulff (1987)
7. Materials Science and Engineering W.D. Callister Wiley

Course Title: Fundamentals of Scanning Probe Microscopy

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY9C04
Credits	:	4	**Course Title**	:	Fund. of Scanning Probe Microscopy
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Tip-Surface Interaction Non-contact regime Intra-molecular Interactions, Electric Dipoles, Inter-molecular interactions: Physical models, ion-dipoles, Keesom forces, Dispersion Force, Contact regime Hamaker theory, surface energies, Dejaugin approximation, contact mechanics, Hertz model, JKR model, DMT model

(12 Lectures)

Unit-2

Atomic Force Microscope (AFM) AFM components, AFM calibration, Contact Mode Scans Force Spectroscopy Cantilever mechanics, Approach-retract curves, Processing Force curves, Modulus and adhesion Maps, Lateral Force Microscopy, Conducting Atomic Force Microscopy, Nano-indentation

(12 Lectures)

Unit-3

Dynamic AFM methods Point Mass Model of Dynamic AFM, frequency response, conservative and dissipative interaction forces, interacting with the surface, Analytical theory of Dynamic AFM : Excited probe interacting with sample (linear theory), Amplitude and Frequency modulation AFM, Non-linear/dissipative interactions, Attractive and Repulsive Regimes and Phase Contrast Modualtion AFM, Reconstructing Surface Forces Relationship between Frequency shift and Potential Energy, reconstruction of interaction force from frequency shift in FM-AFM, Experimental details of FM-AFM measurements

(12 Lectures)

Unit-4

Dynamic AFM for Electrostatics/Magnetic/Biology Measuring Electrostatic Forces, Measuring Magnetic Forces, Dynamic AFM in Liquids, Specialized dynamic-AFM based techniques for physical property measurements: Piezoresponse force microscopy, Scanning non-linear dielectric microscopy, Magnetic exchange force microscopy

(12 Lectures)

Unit-5

Scanning Tunneling Microscopy Quantum tunneling, WKB approximation for field emission, STM instruments and its components, Scanning tunneling spectroscopy, Inelastic electron tunneling spectroscopy; Atomic/molecular manipulations, spin-polarized STM, radio-frequency STM

(12 Lectures)

References

1. Scanning Probe Microscopy and Spectroscopy: Methods and Applications, Roland Wiesendanger, Cambridge University Press, 1994

2. Fundamentals of Scanning Probe Microscopy, V. L. Mironov, The Russian Academy of Sciences, Institute for Physics of Microstructures, 2004

3. Scanning Probe Microscopy: Electrical and Electromechanical Phenomena at the Nanoscale, Sergei V. Kalinin, Alex Gruverman, Springer-Verlag New York, 2007

4. Scanning Probe Microscopy: Atomic Force Microscopy an Springer-Verlag Berlin Heidelberg, 2015.

5. Springer Handbook of Nanotechnology, Ed. Bharat Bhushan, Springer-Verlag Berlin Heidelberg, 2010

Course Title: Alloy Design and Development

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY10E04
Credits	:	4	**Course Title**	:	Alloy Design and Development
L+T+P	:	2+0+2	**Contact Hours**	:	30 (L) + 60(P)

Unit-1

Concept and of alloy design, Steps in alloy design, Significance of alloy design. Single phase, dual phase and multiphase materials, Effect of size, shape and distribution of second phase on mechanical and magnetic properties of alloys. Precipitation and particle coarsening, re-crystallization and grain growth. Solid/Liquid phase transformation in pure metals, single phase alloys, constitutional super cooling and eutectic alloys.

(15 Lectures)

Unit-2

Standards in alloy steels – Study of a few selected standards. Quasicrystalline alloys, Alloy steel design for better tensile strength, ductility, toughness, fatigue strength, creep strength, wear resistance and elevated temperature strength. Alloy design of lightweight, high strength, corrosion resistance Non Ferrous alloys, Magnetic alloys, Multicomponent alloys and their Applications. Different synthesis routes and their effect on properties of Alloys.

(15 Lectures)

List of Experiments

1. Synthesis of alloys through different synthesis routes e.g. mechanical alloying, solid state synthesis, arc melting, and induction melting.
2. Effect annealing temperature on phase revolution and properties of different alloys.
3. Effect annealing condition on phase revolution and properties of different alloys.
4. Mechanical, Magnetic and corrosion behaviors of different alloys.
5. Development of important Alloys.

References

1. ASM Handbook, Vol.1 & 2, Properties and Selection: Metals Park, Ohio.
2. Boyer, H.E.(ed.), Selection of Materials for component Design: Source Book, American Society for Metals, Metals Park, Ohio
3. Ashby, M.F. Materials Selection in Mechanical Design, New York: Pergamon, 1992.
4. Ranganathan S., Arunachalam V.S. and Cahn R.W. (Eds.), Alloy Design, Indian Academy of Science, Bangalore,1981.
5. Tien John K. and Ansell George S. (Eds.), Alloy and Micro structural Design, Academic Press.
6. Structure & Properties of Alloys – Robert M. Brick, Robet B. Gordon & Arthur Phillips, Eurasia Publishing House (private) Ltd., New Delhi
7. Metals Hand Book Ninth Edition – Vol 1

Course Title: Materials Synthesis and Processing

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY11E04
Credits	:	4	**Course Title**	:	Materials Synthesis and Processing
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Introduction: Materials processing science with special emphasis on processing of polymers and ceramics and metals

(2 Lectures)

Unit-2

Polymer processing: Rheology of polymeric materials, Compounding of plastics, processing techniques: Compression, Transfer, injection, blow molding, Extrusion, Calendaring, Thermoforming, Rotational molding, Compounding and processing of rubber (both latex and dry rubber) with different formulations: Casting, rubber extrusion, Dip coating (gloves, balloons etc.), fibre spinning and manufacturing processes. (12 Lectures)

Unit-3

Ceramic processing: Processing of traditional ceramics- spray granulation, Pressing, Slurry processing, Slip casting, Pressure casting, Tape casting, Gel casting, Injection molding, Extrusion; Rapid prototyping through Additive manufacturing, Electrophoretic deposition, Production of ceramic fibres, Electro-spinning; Drying, Binder burnout, Green machining, Sintering; Sol-gel processing, Thermal and plasma spraying, Thick and thin film coatings- PVD and CVD techniques; Vapor infiltration techniques (18 Lectures)

Unit-4

Metallic processing: Casting process- major casting techniques, Solidification and volume shrinkage, Casting design and defects, Fundamentals of deformation processing, Deformation work, Hot and cold working, Few forming processes and defects; Metal removal process- Mechanical machining methods, Single and multiple point machining, Introduction to non-traditional machining, Metal joining process- Concepts of Fusion and solid state welding processes, Brazing and soldering, Welding defects; Introduction to powder Metallurgy Design aspects: General principles of materials selection and design based on requirements of function, Property, Processability and cost; Quantitative methods of materials selection, Normalization of properties, Weighting factors, Materials performance index; Design of engineering structures from the atomic- and nano-scales to macroscopic levels; Case studies- modern metallic, ceramic, polymeric and biomaterials devices and components (16 Lectures)

Unit-5

Design aspects: General principles of materials selection and design based on requirements of function, Property, Processability and cost; Quantitative methods of materials selection, Normalization of properties, Weighting factors, Materials performance index; Design of engineering structures from the atomic- and nano-scales to macroscopic levels; Case studies- modern metallic, ceramic, polymeric and biomaterials devices and components (12 Lectures)

References

1. P. Boch, J-C. Nièpce, Ceramic Materials: Processes, Properties, and Applications, WileyISTE, 2007.
2. J-H. He, ElectrospunNanofibres and Their Applications, SmithersRapra Technology, 2008.
3. Z. Tadmor, C.G. Gogos, Principles of Polymer Processing, 2nd ed., Wiley International, 2006.
4. T.A.Osswald, Polymer Processing Fundamentals, HanserPublcations, 1998.
5. M.N. Rahaman, Ceramic Processing and Sintering, 2nd ed.,, CRC press
6. F.C. Campbell, Elements of Metallurgy and Engineering Alloys, ASM International, 2008.
7. J. Beddoes, M.J. Bibby, Principles of Metal Manufacturing Processes, Elsevier, 2003.
8. G.E. Dieter, Mechanical Metallurgy,McGraw-Hill,3rd ed.,1986.
9. E. Degarmo, J.T. Black and R.A. Kohser, Materials and Processes in Manufacturing, 9th ed., Wiley, 2002.
10. S. Kalpakjian, S.R. Schmid, Manufacturing Engineering and Technology, 6th ed., Pearson,2009.

Course Title: Renewable Energy: Solar and Hydrogen

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY12E04
Credits	:	4	**Course Title**	:	Renewable Energy: Solar and Hydrogen
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Solar Energy: Fundamental and Material Aspects: Fundamentals of photovoltaic Energy Conversion Physics and Material Properties, Basic to Photovoltaic Energy Conversion: Optical properties of Solids. Direct and indirect transition semiconductors, interrelationship between absorption coefficients and band gap recombination of carriers.

(15 Lectures)

Unit-2

Solar Energy: Different Types of Solar Cells: Types of Solar Cells, p-n junction solar cell, Transport Equation, Current Density, Open circuit voltage and short circuit current, Brief description of single crystal silicon and organic and Polymer Solar Cells, Elementary Ideas of Advanced Solar Cells e.g. Tandem Solar cells, Solid Liquid Junction Solar Cells, Nature of Semiconductor, Principles of Photoelectrochemical Solar Cells.

(15 Lectures)

Unit-3

Hydrogen Energy: Fundamentals, Production and Storage: Relevance in relation to depletion of fossil fuels and environmental considerations. Solar Hydrogen through Photoelectrolysis, Physics of material characteristics for production of Solar Hydrogen. Brief discussion of various storage processes, special features of solid hydrogen storage materials, Structural and electronic characteristics of storage materials. New Storage Modes.

(20 Lectures)

Unit-4

Hydrogen Energy: Safety and Utilization: Various factors relevant to safety, use of Hydrogen as Fuel, Use in Vehicular transport, Hydrogen for Electricity Generation, Fuel Cells, Various type of Fuel Cells, Applications of Fuel Cell, Elementary concepts of other Hydrogen- Based devices such as Hydride Batteries.

(10 Lectures)

References

1. Solar Cell Devices-Physics :Fonash
2. Fundamentals of Solar Cells Photovoltaic Solar Energy :Fahrenbruch & Bube
3. Phoptoelectrochemical Solar Cells: Chandra
4. Hydrogen as an Energy Carrier Technologies Systems Economy : Winter & Nitch (Eds.)
5. Hydrogen as a Future Engery Carrier : Andreas Zuttel, Andreas Borgschulte and Louis Schlapbach

Course Title: Nanostructures and Their Properties

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY13E04
Credits	:	4	**Course Title**	:	Nanostructures and Their Properties
L+T+P	:	2+0+2	**Contact Hours**	:	30 (L) + 60(P)

Unit-1

Introduction to nanomaterials Size Dependent properties. Bulk to Nano Transitions. Method of Synthesis: Thermal and ultrasound decomposition methods. Reduction methods. Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductor nanoparticles. High energy ball milling and mechanical attrition. Thermal evaporation. Sputtering. Laser ablation. Chemical vapour deposition. Molecular beam epitaxy. Thermal spraying. Electro and electroless deposition. Brief description of OD,1D,2D nanomaterials e.g. Quantum wells, wires and dots. Size and dimensionality effects. Excitons. Single electron tunneling. Applications in infrared detectors and quantum dot lasers. Magnetic properties of nanocrystalline materials. Nanostructured ferroelectric materials and their properties.

(15 Lectures)

Unit-2

Carbon Nanostructures: Nature of Carbon Clusters, Discovery of C60, Structure of C60 and its Crystal, Superconductivity in C60, Carbon Nanotubes: Synthesis, Structure, Electrical and Mechanical Properties. Graphene: Discovery, Synthesis and Structural Characterization through TEM, Elementary Concept of its applications. Properties of carbon nanotubes. Inorganic nanotubes and nanorods, nanoporous materials.

(15 Lectures)

List of Experiments

1. Synthesis of nanomaterials through different methods Mecahnical-milling, Sol-gel etc
2. Characterizations of nanomaterial through XRD TEM SEM AFM and other techniques.
3. Synthesis of Carbon Nanotubes through CVD.
4. Characterizations through XRD/TEM
5. Synthesis of Graphene through different methods
6. Characterizations of Graphene through XRD TEM.
7. Different properties of carbon nanostructures.

References

1. Introduction to Nanotechnology: Poole and Owners
2. Nano Essentials: T. Pradeep
3. Quantum Dots : Jacak, Hawrylak and Wojs Handbook of Nanostructured Materials and Nanotechnology : Nalva (editor)
4. Nano Technology/ Principles and Practices: S.K. Kulkarni
5. Carbon Nanotubes: Silvana Fiorito 6. Nanotechlongy: Richard Booker and Earl Boysen

Course Title: Biomedical Instrumentation

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY14E04
Credits	:	4	**Course Title**	:	Biomedical Instrumentation
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Basic principles of biomedical electronics. Distribution of electrical potentials in different parts of the body. Their magnitude and relationship to the physical status. Physical anatomy and its relation to bi-electric signals. Processing of bio-electronic signals and different types of transducers for acquisition. Recording systems, general consideration of electronic recording amplifier. Pre-amplifier, main amplifier and driver amplifier. Consideration of noise. Different types of digital recorder.

(15 Lectures)

Unit-2

Need for imaging the human body. Imaging techniques, computer assisted tomography (CATSCAN); Basic principles and overall design. Nuclear resonance techniques; full body nuclear magnetic resonance scanners (NMR);Design of NMR scanner and its applications; Ultrasound instrumentation and its applications; thermography and applications. Case studies of typical instrumentation requirements in Electroencephalography (EEG), Electrocardiography, photo cardiograph, and Electromyography (EMG); Different techniques of displaying information. Display systems. Use of oscilloscope, cardioscope, and multichannel displays. Patient safety, electronic shock hazards in biomedical instrumentation. Leakage current and their merits. Instrumentation grounding techniques and patient monitoring systems.

(15 Lectures)

Unit-3

Computer based imaging : Computer applications in medical imaging : Basics; Computers in nuclear medicine; nuclear medicine computer systems; software in nuclear medicine; digital subtraction radiography; computerised ultrasonography; X-ray computerised tomography; computerised emission tomography; nuclear magnetic resonance.

(15 Lectures)

Unit-4

Therapeutic equipments; cardiac pace makers; defibrillators; surgical diathermy;lasers and biomedical electronics; short-wave and microwave diathermy.Computeres in medical research : Signal processing; model building and simulation; Monte Carlo technique; cell kinetics; operational research; statistical research; multivariate analysis; numerical taxonomy; risk profiles; Framingham study; computer networking.

(15 Lectures)

References

1. R.S. Khandpur, Handbook of Biomedical instrumentation, McGraw-Hill Education, 1987
2. Leslie Cromwell, Biomedical instrumentation and measurements, Prentice-Hall, 2011
3. R.D. Lele, Computers in medicine, Tata McGraw-Hill Pub., 1988

Course Title: Industrial Process Control

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY15E04
Credits	:	4	**Course Title**	:	Industrial Process Control
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Transducer and Instrumentation Basics: Principles of transduction, resistive, capacitive, inductive, piezoelectronic, digital etc. temperature, strain, pressure and flow transducers mounting, characteristics and responses.Digital transducers, digital encoders rotating optical transducer, level transducer.Signal conditioning system, offsetting linerization, linear variable differential transducer (LVDT). Instrumentation amplifiers, differential input and DC instrumentation amplifiers. Data Acquisition and Conversion Systems : Microprocessor bases data acquisition system S/H circuits, Analog multiplexers, DAC & ADC converters, signal channel and multichannel IC's, successive approximation register (SAR), converter specifications, resolution, accuracy and speed, recorders, display systems.

(15 Lectures)

Unit-2

Industrial Process Control : Basic process elements, process model identification, feedback control system, feedback and feed forward and cascade control, Analog controllers, Proportional Integral derivative (PID) controller, Turning of analog controllers.

(15 Lectures)

Unit-3

Micro Controllers : Logic control systems, Programmable Logic Controller (PLD), basic functions of PIC, basic architecture, ladder diagram, programming, mirocontroller8031/8051, a elements of 16 bit microcontroller (8097).Alarm signal generation for a process (e.g. heating etc.,) Direct digital control (DDC) algorithm.

(15 Lectures)

Unit-4

Interfacing - Standards for Instrumentation : Analog signal transmission, 4.20 mA current loop, Digital transmission, synchronous/asynchronous (8251 USART), parallel data transmission (PPI 8255), control parallel printer prot. Bus standards : 222 C, Rs-422, IEE 802.4, General purpose interfaced bus (GPIB), IEE 488. Interfacing with stepper motor. Interfacing with DAC & ADC.

(15 Lectures)

References

1. D.V.Hall, Microprocessors and Interfacing, Tata McGraw Hill Education Private Limited, 2005
2. Barry E. Jones, Instrumentation measurement and feedback, Tata McGraw Hill Education Private Limited, 1977

Course Title: Nanoelectronics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY16E04
Credits	:	4	**Course Title**	:	Nanoelectronics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Nanoelectronics: Why? Device scaling, Moore's law, limitations, role of quantum mechanics, Nanostructures: Impact, technology and physical consideration; Mesoscopic observables Preliminaries : Basic Quantum mechanics and Fermi statistics, Metals, Insulators and Semiconductor, Density of states (DOS) in 0D, 1 D, 2D and 3D, DOS in disordered materials, Physics of organic semiconductors: concept of HOMO and LUMO, band gap etc. Novel molecules (Pentacene, carbon nanotube, Fullerenes and its derivatives etc.) and conjugated polymers (Polyacetylene, P3HT, PEDOT:PSS etc.).

(15 Lectures)

Unit-2

Semi-classical theory of transport in nanostructures: Modification of Ohm's law: elastic resistor, ballistic and diffusive transport, conductivity, quantum capacitance, diffusion equation for ballistic transport, Nanotransistor. Voltage-drop, Quasi-Fermi levels, Landauer formula, electrostatic potential versus electrochemical potential, Boltzmann transport equation. Spin voltages. Entropy driven processes in electrical transport, Seebeck effect, Peltier effect, Heat current, second law of thermodynamics, entropy.

(15 Lectures)

Unit-3

Two terminal quantum dot and quantum wire devices: Equilibrium in two terminal devices, Current flow in the presence of a bias, numerical technique for self-consistent estimation of V-I ,Current flow, quantum of conductance. Three-terminal devices: Field Effect Transistors (FETs): Ballistic quantum wire FETs, conventional MOSFETs, CMOS, short channel and narrow width, hot electron effect, punch-through and thin gate oxide breakdown, OFET;

Spintronics: Spin, propagation, detection, spinFETs.

(15 Lectures)

Unit-4

Nano-fabrication techniques: Top-down and bottom-up strategies, advantages/disadvantages/ limitations, e-beam lithography, Focussed Ion beam milling, self-organized structures, laser nano-patterning, nano-imprint, electrochemical synthesis, Fabrication of OEDs etc.

(15 Lectures)

References

1. David Ferry , Transport in Nanostructures Cambridge University Press (1995)
2. M. Baldo, Introduction to Nanoelectronics (Lecture Notes; May 2011 MIT).
3. S. Datta, Electronic Transport in Mesocopic Systems; Cambridge University Press (1995).

4. S. Datta, Quantum Transport: Atom to Transistor; Cambridge University Press (2005).

5. M. Lundstrom and J. Guo, Nanoscale Transistors; Physics, Modeling, and Simulation, Springer (2006).

6. P.W. Atkins and R.S. Friedman, Molecular Quantum Mechanics; Oxford University Press, 3rd edition (1997).

7. M. Stepanova and S. Dew, Nanofabrication: Techniques and Principles; Springer-Verlag (2012)

Course Title: Statistical Analysis Techniques in Nuclear and Particle Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY17E04
Credits	:	4	**Course Title**	:	Stat. Analy. Techn. in Nucl.& Part. Phys.
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Probability theory: Classical probability, Frequentist probability, Subjective (Bayesian) probability, Komogorov axiomatic approach, Probability distributions, PDFs in more dimensions, Mean, variance and covariance, General Properties of Distributions Binomial Distribution, Poisson Distribution, Gaussian Distribution, Chi-Square (χ^2) Distribution, Gamma Distribution, Commonly used distributions, Conditional probability, Bayes theorem, The likelihood function.

(15 Lectures)

Unit-2

Inference : Review: Random Errors, Error Propagation, Systematic Errors, Basic Estimators, Maximum Likelihood, Inference: Bayesian inference, Error propagation with Bayiesian inference, Choice of the prior, Frequentist inference, Maximum likelihood estimates, Estimate of Gaussian parameters, Estimator properties, Neymans confidence intervals, Binomial intervals, Approximate error evaluation for maximum likelihood estimates, Two-dimensional uncertainty contours, Likelihood function for binned samples, Combination of measurements, Hypothesis tests

(15 Lectures)

Unit-3

Essential Statistics for Data Analysis : Measures of Centrality, Measure of Dispersion, LEAST SQUARES, Fitting Binned Data, Linear Least Squares and Matrices, Chi-Square (χ^2) Test, Students t Test, Simple Linear Regression, Nonlinear Regression, Correlation, Time Series Analysis, Frequency Domain Analysis, Counting Statistics.

(15 Lectures)

Unit-4

Hypothesis tests and Discoveries Level : The Neyman Pearson lemma, Projective likelihood ratio, Fisher discriminant, Artificial Neural Net-work, Boosted Decision Trees, Overtraining, Upper limits and Discoveries level: Poisson upper limit, Feldman Cousins intervals, Upper limits for event counting experiments, The modified frequentist approach, Treatment of nuisance parameters, Profile likelihood, Variations on test statistics, Random Number generator, Review of Monte Carlo Monte Carlo technique.

(15 Lectures)

References

1. Statistics for Nuclear and Particle Physicists, Louis Lyons, Cambridge University Press (2018)
2. Statistical Methods in Experimental Physics, Frederick Jame, World Scientific Publishing Co. Pre. Ltd (2nd Edition).

3. Data Analysis in High Energy Physics: A Practical Guide to Statistical Methods, edited by Olaf Behnke, Kevin Kröninger, Grégory Schott, Thomas Schörner-Sadenius, Wiley & sons

4. Statistical Methods for Data Analysis in Particle Physics, Luca Lista, Springer.

Course Title: Introduction of Astrophysics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY18E04
Credits	:	4	**Course Title**	:	Introduction of Astrophysics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Stellar Structure and Evolution : Stellar Structure and Evolution: Virial Theorem, Formation of Stars, Hydrostatic Equilibrium, Integral Theorems on pressure, density and temperature, Homologous Transformations, Polytropic gas spheres Lane Emden Equation and its solution, Energy generation in stars, P-P and C-N cycles, Radiative and Convection transport of energy, Equations of stellar structure and their solution, Evolution of stars of different masses, pre- and post main- sequence evolution.

(20 Lectures)

Unit-2

Gravitational Collapse and relativistic Astrophysics : Newtonian theory of stellar equilibrium, White Dwarfs, Electron degeneracy and equation of States, Chandrasekhar Limit, Mass-Radius relation of WD. Neutron Stars, Spherically symmetric distribution of perfect fluid in equilibrium. Tolman-Oppenheimer-Volkoff (TOF) equation, Mass-Radius relations of NS. Pulsars, Magnetars, Gamma ray bursts. Black holes, Collapse to a black hole (Oppenheimer and Snyder), event horizon, singularity.

(10 Lectures)

Unit-3

Galaxies : The milky way Galaxy, Distribution of stars, Morphology, Kinematics, Interstellar medium, Galactic center. Classification of galaxies, Hubble sequence, Ellipticals, Lenticularsand spiral galaxies and their properties, distribution of light and mass in galaxies.

(10 Lectures)

Unit-4

Overview of Modern Astronomy : 21-cm hydrogen line, cosmic radio sources, quasars, gravitational lensing, Expansion of the Universe and determination of Hubbles constant, gamma ray bursters. Sources of Gravitational Waves.

(10 Lectures)

Unit-5

Experimental methods in Nuclear Astrophysics : Coulomb dissociation, Trojan Horse Method, ANC method, recent applications using Radioactive beams.

(5 Lectures)

References

1. Stellar Interiors - Physical Principles, Structure, and Evolution by C. J. Hansen, S. D.
2. Kawaler, V. Trimble (Springer, 2004)

3. Stellar Structure and Evolution by R. Kippenhahn and A. Weigert (Springer, 1996)
4. Basics of Astronomy – IGNOU course book PHE-15 Astronomy and Astrophysics, 2006
5. Modern Astrophysicsby Carrol & Ostlie (Addison Wesley, 1996)
6. The Physical Universe by F. Shu (University Science Books, 1982)
7. Principles of Stellar Structure Vol. I & II by J. P. Cox & R. T. Giuli (Gordon & Breach, 1968)
8. An Introduction to the Study of Stellar Structure by S. Chanrdrasekhar (Dover, 1968)
9. Stellar Interiors by D. Menzel, P. L. Bhatnagar & H. K. Sen (Chapman & Hall, 1963)
10. Galactic Astronomy by J. Binney & M. Merrifield (Princeton Univ. Press, 1998)
11. Textbook of Astronomy & Astrophysics by V. B. Bhatia (Narosa, 2001)

Course Title: Nuclear Reactor Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY19E04
Credits	:	4	**Course Title**	:	Nuclear Reactor Physics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

Nuclear energy and Neutron diffusion : Binding energy - Nuclear reactions - Nuclear cross sections, Macroscopic cross sections, Mechanism of fission, Products of fission - Energy release from fission - Reactor power - Fuel burn up, Consumption - Multiplication factor - neutron balance and conditions for criticality - Conversion and breeding Classification of reactors.

(10 Lectures)

Unit-2

Diffusion of neutrons : Flux and current density - Equation of continuity - Fick's law - Diffusion equation – Boundary conditions and solutions - Diffusion length - Reciprocity theorem.

(10 Lectures)

Unit-3

Neutron moderation : Energy loss in elastic collision - moderation of neutrons in Hydrogen - Lethargy - Moderation of neutrons - Fermi's age theory - Moderation with absorption. Fermi theory of Bare thermal reactor : Criticality of an infinite reactor - One region finite thermal reactor - Critical equation - Optimum reactor shape.

(10 Lectures)

Unit-4

Reactor kinetics : Infinite reactor with and without delayed neutrons - Stable period - Prompt jump - Prompt criticality - Negative reactivity - Changes in reactivity - Temperature coefficient - Fission poisoning.

(10 Lectures)

Unit-5

Control and shielding : Control Rod , Fuel management, Natural reactors, Thermal reactors - Intermediate reactors, Fast reactors Breeding, The Thorium converter Light water.

(10 Lectures)

Unit-6

Reactors : Heavy water Reactors Heat generation and removal Radiation shielding and reactor safeguards Evolution of reactors -Reactor properties over life - core life estimation.

(10 Lectures)

References

1. John.R Lamarsh, Introduction to Nuclear Reactor Theory, Addison Wesley Publishing Company 2nd printing (1992)

2. Paul .F. Zweifel, Reactor Physics, McGraw Hill Book Company (1973) India.

3. Richard Stepheson, Introduction to nuclear Engineering, McGraw Hill Book Company (1974) New York.

4. Suresh Gard, Feroz Ahmed and L. S Kothari, Physics of Nuclear Reactors, Tata McGraw Hill Pub. Co. Ltd, London.

5. Samuel Glasstone and Edmund , Nucleaar reactor theory

Course Title: Data Analysis and Simulation in Particle Physics

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY20E04
Credits	:	4	**Course Title**	:	Data Analy. and Sim. in particle Physics
L+T+P	:	4+0+0	**Contact Hours**	:	60 (L)

Unit-1

C/C++ Programming concepts : Overview- Fundamentals of computer architecture and operation - Programming inC and C++ languages - Data types, int, char, float etc. - C expressions, arithmetic operations, relational and logic operations - Concepts of variables, statements and function calls - Assignment statements, extension of assignment to the operations - primitive input output and print functions – conditional execution using if, else. switch and break statements- Concepts of loops, for, while and do-while-Arrays and pointers- One/Two dimensional arrays and example of iterative programs using arrays- Matrix computations- Sub-programming, functions- Strings -Structure and unions.- Defining C structures, passing structures as arguments- File 1 /0- Simple programs.

(15 Lectures)

Unit-2

Data Analysis : Reconstruction of raw detector data, Charged-particle trajectories, Energy reconstruction, Quark jets, Stable-particle identification, Displaced vertices, unstable-particle reconstruction, Monte Carlo event generators, detector response, Beyond the detector, Multivariate techniques.

(15 Lectures)

Unit-3

Software for Data Analysis : Standard Analysis Packages, Cern Root, Basic idea of ROOT: Histogram, Graph, fitting to Pseudo Data, A Little C++, Math Libraries in ROOT, Linear Algebra in ROOT Trees:Data Handling, Organization, Storage, Data Analysis Capabilities.

(15 Lectures)

Unit-4

GEANT4 Simualtion : Geant4 Scope of Application, Overview of Geant4 Functionality including tracking, geometry, physics models and hits. Examples: nuclear physics and medical physics.

(15 Lectures)

References

1. E. Balgurusamy : Programming in ANSI C, Tata McGraw Hill
2. V Rajaraman, Computer Oriented Numerical Methods, 3rd Ed. (Prentice-Hall, New Delhi, 1993).
3. $https : //root.cern.ch/guides/users - guide$
4. $https : //geant4.web.cern.ch/support/user_documentation$

Course Title: Radiation Safety

Programme	:	M.Sc. (Physics)	**Course code**	:	MSPHY21E02
Credits	:	2	**Course Title**	:	Radiation Safety
L+T+P	:	2+0+0	**Contact Hours**	:	30 (L)

Unit-1

Interactions of Radiation with Matter : Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric effect, Compton scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), interaction of neutrons with matter.

(10 Lectrures)

Unit-2

Radiation Quantities and Units : Activity (Becquerel and Curie), energy, exposure (C/kg and Roentgen), air kerma, absorbed dose (Gray and rad), radiation weighting factors, tissue weighting factors, equivalent dose (Siever and rem), effective dose (Sievert and rem) Biological Effects of Radiation Introduction to cell, direct and indirect interactions, effects of radiation on living cells, chromosomal aberration, somatic and genetic effects, deterministic and stochastic effects, acute and chronic exposure, partial body and whole body exposures.

(10 Lectrures)

Unit-3

Radiation Hazard Evaluation and Control : Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation: individual and work place monitoring, application of time, distance and shielding; shielding material, exposure rate constant, types of radiography installations: enclosed installation, opentop, open field; planning of radiography enclosure, controlled areas and supervised areas, shielding calculation for enclosed installations, scattering, Albedo, skyshine, calculation of cordon-off distance, safety in radiography installations: enclosed, open top and field radiography, tracking of lost sources, source storage facilities, safe work practices, safety aspects of high energy accelerators,

(10 Lectrures)

References

1. Radiation Safety: Management and Programs, Haydee Domenech , Springer 2017 edition .
2. Radiation Safety Procedures and Training for the Radiation Safety Officer: Guidance for Preparing a Radiation Safety Program, by John R Haygood, iUniverse (17 September 2013).
3. Radiation Safety in Nuclear Medicine, A Practical, Concise Guide, Gopal B. Saha, Springer.
4. Physics for Radiation Protection, James E. Martin, Wiley-VCH Verlag GmbH & Co. KGaA .
5. Applied Physics of External Radiation Exposure, Dosimetry and Radiation Protection, Antoni, Rodolphe, Bourgois, Laurent, Springer.