UNIVERSITY OF DELHI

MASTER OF SCIENCE in PHYSICS

(Two Years Programme-NEP)

(Effective from Academic Year 2025-26)

Proposed Postgraduate Curricular Framework 2025
(based on NEP 2020)

LEVELS 6 AND 6.5

Programme Specific Outcomes (PSOs)

- ❖ Understanding the basic concepts of physics particularly concepts in classical mechanics, quantum mechanics, statistical mechanics and electricity and magnetism to appreciate how diverse phenomena observed in nature follow from a small set of fundamental laws through logical and mathematical reasoning.
- ❖ Learn to carry out experiments in basic as well as certain advanced areas of physics such as nuclear physics, condensed matter physics, nanoscience, lasers, and electronics.
- ❖ Understand the basic concepts of certain sub fields such as nuclear and high energy physics, atomic and molecular physics, solid state physics, and plasma physics, and astrophysics, general theory of relativity, nonlinear dynamics and complex systems.
- ❖ Gain hands-on experience to work in applied fields.
- ❖ Enhancing skills in experimental techniques and computation
- ❖ Gain a thorough grounding in the subject to be able to teach it at college and school levels.
- ❖ Viewing physics as a training ground for the mind to develop a critical attitude and a faculty of logical reasoning that can be applied to diverse fields.

Programme Structure

The M. Sc. programme is a two-year course divided into four semesters. A student is required to complete **88** credits (LEVEL 6 AND 6.5) for the completion of the course and the award of degree. The student who exits after one year at level 6 (44 credits) and acquires required credits shall be awarded with PG diploma. The M.Sc. Physics Programme would make the students competent in natural science, viz., Physics, and help them understand its role in modern day technology. Overall, the course would enable the students to understand the fundamental concepts and experimental methods of physics which would help them to innovate/apply/generate new devices/applications/insights/knowledge. Knowledge gained through the open electives would be an asset in branching out in fields other than physics.

		Semester	Semester
Part – I	First Year	Semester I	Semester II
Part – II	Second Year	Semester III	Semester IV

PG curricular structure for 2 year PG Programmes (3+2)

Course Credit Scheme for M.Sc. Physics

Semester	Core Courses			Elective Course			SBC			Total Credits
	No. of papers	Credits (L+T+P)	Total Credits	No. of papers	Credits (L+T+P)	Total Credits	No. of papers	Credits (L+T+P)	Total Credits	
I	03 (3DSC) DSC1 DSC2 DSC3	9+3+0	12	02 (DSE1) (DSE2/ GE1)	4 4	8	1	2	2	**22**
II	03 (4DSC) DSC4 DSC5 DSC6	9+3+0	12	02 (DSE3) (DSE4/ GE2)	4 4	8	1	2	2	22
III	02 DSC7 DSC8	8	8	DSE5 DSE6 DSE7 3DSEs or 2DSEs + 1 GE3	4 4 4	12	1	2	2	22
IV	02 DSC9 DSC10	8	8	DSE8 DSE9 DSE10 3DSEs or 2DSEs + 1 GE4	4 4 4	12	1	2	2	22
Total Credits for the Course			40			40			8	88

The mode(s) of internal assessment will vary from course to course. The internal assessment marks will be based on performance in tests / quizzes / assignments / project work /

presentations / attendance, etc. All laboratory courses will be evaluated based on continuous evaluation and end-of-semester examination as per the university's rules.

DSC: Department-Specific Core Course
DSE: Department-Specific Elective Course
SBC: Skill-Based Course

M. Sc. Programme (Semester-wise)

Semester I					
Number of Core courses: 3		Credits in each core course			
CORE COURSES	Page	Lecture (L)	Practical (P)	Tutorial (T)	Credits
<u>PH-DSC4101: Classical Mechanics</u> *(Essential for Nuclear physics, GTR, Astrophysics, Solid State Physics, Plasma Physics, Relativistic dynamics, EMT and Electrodynamics)*	7	3	0	1	4
<u>PH-DSC4102: Quantum Mechanics I</u> *(Essential for Advanced Solid State Physics, Cond. Matter Physics, Nuclear Physics, Particle Physics, QFT, Quantum information)*	9	3	0	1	4
<u>PH-DSC4103: Electronics</u> *(Essential for Nuclear Physics, Laser Spectroscopy Nano science/physics, Adv. Electronics theory, Adv. Solid state Physics, All labs)*	11	3	0	1	4
Total credits in Core courses					12
Number of Elective courses: 2 (DSE1, DSE2/GE1)					8
<u>DSE – 1 (Pool A: Select one DSE Course)</u>					
<u>PH-DSE4111: Foundational Laboratory in Experimental Physics</u> *(Essential for all adv. Labs and corresponding theory papers and several standalone theory courses)*	13	0	4	0	4
<u>PH-DSE4112: Experimental Laboratory in Materials and Optical Physics</u> *(Essential for all adv. Labs and corresponding theory papers and several standalone theory courses)*	15	0	4	0	4
<u>DSE -2 (Pool-B: Select one DSE Course or GE)</u>					
<u>PH-DSE4113 Mathematical Physics</u> *(Recommended for QM2, QFT, Particle Physics, GTR, Fluid dynamics)*	18	3	0	1	4

PH-DSE4114 Relativistic Dynamics and Applications *(Recommended for EMT and Electrodynamics, GTR, QFT, Particle Physics)*	20	3	0	1	4
PH-DSE4115 Experimental Techniques in Nuclear Science	22	3	0	1	4
PH-DSE4116 Materials Characterization Techniques	24	3	0	1	4
PH-DSE4117 Techniques in Theoretical Physics *(Essential for EMT and Electrodynamics, GTR, QFT, Particle Physics)*	26	3	0	1	4
Total credits in Elective courses:					8
No. of Skill Based courses (SBC): 1 (Total credits: 2)					
PH-SBC4171 Workshop skills	28	0	2	0	2
PH-SBC4172 Python for physicists	29	0	2	0	2
PH-SBC4173 Radiation Safety	30	1	1	0	2
PH-SBC4174 Order of Magnitude Physics	32	1	1	0	2
PH-SBC4175 Strategies for Scientific Dialogue in Research	34	1	1	0	2
Total credits in SBC courses					2
Total credits in Semester I					22

Semester II					
Number of Core courses: 3		Credits in each core course			
CORE COURSES:	Page	Lecture (L)	Practical (P)	Tutorial (T)	Credits
PH-DSC4201: Quantum Mechanics II *(Essential for Advanced Solid State Physics, Cond. Matter Physics, Nuclear Physics, Particle Physics, QFT, Quantum information)*	36	3	0	1	4
PH-DSC4202: Electromagnetic theory and Electrodynamics *(Essential for GTR and Cosmology, Plasma Physics, Particle Physics, QFT, Laser and spectroscopy)*	38	3	0	1	4
PH-DSC4203: Solid State Physics (*Essential* for *Laser Spectroscopy Physics at Nanoscale, Adv. Electronics theory, Adv. Solid State Physics, All labs, computational material science, condensed matter physics)*	40	3	0	1	4
Total credits in Core courses					12

Number of Elective courses: 02 (DSE3, DSE4/GE2)					8
DSE – 3 (Pool A: Select one DSE Course)					
PH-DSE4211: Foundational Laboratory in Experimental Physics *(Essential for all adv. Labs and corresponding theory papers and several standalone theory courses.)*	42	0	4	0	4
PH-DSE4212: Experimental Laboratory in Materials and Optical Physics *(Essential for all adv. Labs and corresponding theory papers and several standalone theory courses)*	44	0	4	0	4
DSE – 4 (Pool-C: Select one DSE Course or GE)					
PH-DSE4213 Material Characterization Techniques	47	3	0	1	4
PH-DSE4214 Experimental Techniques in Nuclear Science	49	3	0	1	4
PH-DSE4215 Techniques in Theoretical Physics *(Essential for QFT, Electrodynamics and EMT, GTR, Particle Physics*	51	3	0	1	4
PH-DSE4216:Theoretical Techniques in the Quantum World	53	3	0	1	4
Total credits in Elective courses:					8
Number of Skill-Based courses (SBC): 1 (Total credits: 2)					
PH-SBC4271: Workshop skills	55	0	2	0	2
PH-SBC4272: Computational Physics	56	0	2	0	2
PH-SBC4273: Amateur Astronomy	57	0	2	0	2
PH-SBC4274: Magnet Design and Simulation	58	1	1	0	2
PH-SBC4275: Data Simulation and Interpretation	61	1	1	0	2
PH-SBC4276: Electronic Circuit and Simulation	63	0	2	0	2
PH-SBC4277: Strategies for Scientific Dialogue in Research	64	1	1	0	2
Total credits in SBC courses					2
Total credits in Semester II					22

<u>**Course Wise Content Details for M. Sc. Physics Programme**</u>

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-DSC4101

Course Name: Classical Mechanics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Classical Mechanics DSC	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

The primary objective is to teach the students Classical Mechanics at a level more advanced than what they have learnt in B.Sc. This is a course which forms the basis of Physics of many areas of Physics.

Contents:

Unit I (15 hours)

Newton's laws and symmetries. Generalized coordinates and constraints on dynamical systems. Variational calculus. Action and Euler-Lagrange equations. Cyclic coordinates and conserved quantities, Louville's theorem, Scaling laws, potential reconstruction. Examples. Hamiltonians and Hamiltonian equations. Phase space trajectories. Canonical variables and Poisson bracket. Examples.

Unit II (10 hours)

Kepler problem. Perturbation and precessing orbits. The classical scattering problem. Small oscillations (non-diagonal kinetic and potential terms).

Unit III (8 hours)

Canonical transformations, Generators of infinitesimal canonical transformations. Hamilton-Jacobi equation, Action and angle variables, Adiabatic invariants.

Unit IV (12 hours)

- Rigid Body, Euler angles, the symmetrical top.
- System with infinite degrees of freedom Classical fields : Lagrangian and Hamiltonian formulations Equations of motion. Symmetries and invariance principles, Noether's theorem.

Course Learning Outcomes

Students will be equipped for advanced and specialized courses. The student learns to deal with particle mechanics at an advanced level and to learn the foundations of the classical theory of fields.

Suggested Readings

1. Mechanics, L. D. Landau and E. M. Lifshitz (3rd Ed., Pergamon, 1976).
2. Classical Mechanics, H. Goldstein (Pearson Education, 2014).
3. Classical Mechanics, N. C. Rana and P. S. Jaog (McGraw-Hill, 1991).

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-DSC4102

Course Name: Quantum Mechanics - I

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Mechanics-I DSC	4	3	1	0	

Duration: 60 hours (45L+ 15T)

Course Objectives

The primary objective is to teach the students the physical and mathematical basis of quantum mechanics for non-relativistic systems

Contents:

Unit I (15 hours)

Abstract formulation of Quantum Mechanics: Mathematical properties of linear vector spaces. Dirac's bra and ket notation. Hermitian operators, eigenvalues, and eigenvectors. Orthonormality, completeness, closure. Postulates of quantum mechanics. Matrix representation of operators. Position and momentum representations – connection with wave mechanics. Commuting operators. Generalised uncertainty principle. Change of basis and unitary transformation. Expectation values. Ehrenfest theorem.

Unit II (12 hours)

Quantum Dynamics: Schrodinger picture, Heisenberg picture, Heisenberg equation of motion,

classical limit, solution of the simple harmonic oscillator problem by the operator method, general view of symmetries and conservation laws. Spatial translation – continuous and discrete, time translation. parity, time reversal, Density matrices - properties, pure and mixed density matrices, expectation value of an observable, time-evolution, reduced density Matrix, Bloch sphere.

Unit III (9 hours)

Angular Momentum as generator of rotation. Commutation relations of angular momentum operators, eigenvalues, eigenvectors, ladder operators and their matrix representations. Identical particles: Many-particle systems, exchange degeneracy, symmetric and anti-symmetric wavefunctions. Pauli exclusion principle

Unit IV (9 hours)

Approximate Methods: time-independent non-degenerate perturbation theory (Both Rayleigh-Schrodinger and Brillouin-Wigner), degenerate perturbation theory, variational methods.

Course Learning Outcomes

Students will learn the mathematical formalism of Hilbert space, Hermitian operators, eigenvalues, eigenstates, and unitary operators, which form the fundamental basis of quantum theory. Application to simple harmonic oscillators and hydrogen-like atoms will teach the students how to elegantly obtain eigenvalues and eigenstates for such systems. Students will learn to apply first- and second-order non-degenerate and degenerate perturbation theory. The topic of density matrices, which plays a significant role in quantum information theory and statistical mechanics, will also help the students considerably.

Suggested Readings:

1. Quantum Mechanics, B. H. Bransden & C. J. Joachain (Pearson Education, 2000)
2. Principles of Quantum Mechanics,R. Shankar (3rd Ed., Springer, 2008)
3. Quantum Mechanics (Vol. I),Claude Cohen-Tannoudji, Bernard and Frank Laloe16 (Wiley, 1977)
4. Modern Quantum Mechanics, J. J. Sakurai (Addison-Wesley, 1993)
5. Advanced Quantum Mechanics, F. Schwabl (Springer, 2000)
6. Quantum Mechanics, A. S. Davydov (2nd Ed., Pergamon, 1991)
7. Quantum Mechanics, Eugen Merzbacher (3rd Ed., Wiley, 1997)
8. Quantum Mechanics: Concepts and Applications, Nouredine Zettili (Wiley 2nd edition 2009)
9. The Principles of Quantum Mechanics, P. A. M. Dirac, (International Series of Monographs on Physics,1981).
10. Quantum Computation and Quantum Information, Michael A. Nielsen, Isaac L. Chuang, (Cambridge University Press,2010)

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-DSC4103

Course Name: Electronics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Electronics DSC	4	3	1	0	

Duration: 60 hours (45L+ 15T)

Course Objectives

To build up on the basic knowledge of electronics with the introduction of advanced topics like circuit analysis and applications of semiconductor devices in analog and digital circuits.

Contents:

Unit I (10 hours)

Circuit Analysis: Admittance, impedance, scattering and hybrid matrices for two and three port networks and their cascade and parallel combinations. Review of Laplace Transforms. Response functions, location of poles and zeros of response functions of active and passive systems (Nodal and Modified Nodal Analysis).

Unit II (13 hours)

Physics of Semiconductor Devices: p-n junction, Tunnel Diode, JFET, UJT, 4 layer pnpn device (SCR), Introduction of Power devices: DIAC, TRIAC, accumulation, depletion and inversion, MOSFET: I-V, C-V characteristics. Enhancement and depletion mode MOSFET. Ohmic and Rectifying contacts, Schottky diode, I-V, C-V relations.

Unit III (14 hours)

Analog circuits: Active filters and equalizers with feedback, Phase shift and delay.

Digital Circuits: Introduction to digital IC parameters (switching time, propagation delay, fan out, fan in etc.). TTL, MOS and CMOS gates, Emitter-coupled logic, MOSFET as transmission gate. A/D and D/A converters. Basics of micro-processor and micro-controller (8-bit AVR).

Unit IV (8 hours)

Communication Systems: Amplitude, Angle and Pulse-analog modulation: Generation and detection. Model of communication system, classification of signals, representation of signals.

Course Learning Outcomes

A student of this course is expected to be able to understand the design and functional performance of electronic circuits using various semiconductor devices. In addition, the student will understand the functional properties and characteristics of semiconductor devices in analog & digital circuits using analog and digital signals.

Suggested Readings

1. Network Analysis and Synthesis, F.F. Kuo (2^{nd} Ed., Wiley, 2010)
2. Network Analysis with Applications, W.D. Stanley (4^{th} Ed., Pearson, 2003)
3. Electronic Devices and Circuits, J. Millman and C. C. Halkias and S. Jit (4^{th} Ed., McGraw-Hill, 2015)
4. Integrated Electronics, J. Millman, C. C. Halkias and C. D. Parikh (2^{nd} Ed., McGraw-Hill, 2011)
5. Physics of Semiconductor Devices: J.P. Colinge and C. A. Colinge (KLUWER ACADEMIC PUBLISHERS, NEW YORK)
6. Physics of Semiconductor Devices: S.M. Sze (2^{nd} Edition, Wiley Interscience Publications, John Wiley & Sons)
7. Communication Systems, Simon Haykins (5^{th} Ed., Wiley, 2009)
8. Digital Signal Processing, J. G. Proakis and D. G. Manolakis (4^{th} Ed., Pearson, 2007)
9. Solid State Electronic Devices, B.G. Streetman (7^{th} Ed., Pearson, 2015)
10. Digital Design, M. Mano (5^{th} Ed., Pearson, 2013)
11. Digital Principles and Applications, A.P. Malvino and D.P.Leach (8^{th} Ed., McGrawHill, 2014)

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-DSE4111

Course Name: Foundational Laboratory in Experimental Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Foundational Laboratory in Experimental Physics DSE	4	0	0	4	

Duration: 120 hours (8P/Week)

Course Objective

The major objective of this course is to revise the basic concepts of electronics/nuclear physics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Contents:

Electronics

Unit I-

Device Characteristics and Application

1. p-n junction diodes-clipping and clamping circuits.
2. FET – characteristics, biasing and its applications as an amplifier.
3. MOSFET – characteristics, biasing and its applications as an amplifier.
4. UJT – characteristics, and its application as a relaxation oscillator.
5. SCR – Characteristics and its application as a switching device.

Unit II-

- Linear Circuits

1. Resonant circuits.
2. Filters-passive and active, all pass (phase shifters).
3. Power supply-regulation and stabilization.
4. Oscillator design and study.
5. Multi-stage and tuned amplifiers.
6. Multivibrators-astable, monostable and bistable with applications.
7. Design and study of a triangular wave generator.
8. Design and study of sample and hold circuits.

- Digital Circuits and Microprocessors

1. Combinational.
2. Sequential.
3. A/D and D/A converters.
4. Digital Modulation.
5. Microprocessor application.

Nuclear Physics

Unit III- Detectors

1. G.M. Counters – characteristics, dead time and counting statistics
2. Spark counter-characteristics and range of x-particles in air
3. Scintillation detector-energy calibration, resolution and determination of gamma ray energy
4. Solid State detector – surface barrier detector, its characteristics and applications.

Unit IV-

- Applications

1. Gamma ray absorption-half thickness in lead for 60Co gamma-rays.
2. Beta ray absorption – end point energy of beta particles.
3. Lifetime of a short lived radioactive source..

- High Energy Physics

1. Study of pi-mu-e decay in nuclear emulsions.
2. Study of high energy interactions in nuclear emulsions.

Course Learning Outcomes

At the end of this laboratory course, each and every student is expected to understand the basic concepts of electronics/nuclear physics through experiments, which would immensely help them in acquiring knowledge to tackle various competitive exam questions.

Suggested Readings

Electronics:

1. Electronic Instrumentation and Measurement Techniques, W. D. Cooper and A. D. Helfrick (2nd Ed., Phi Learning, 2008)
2. Electronic Devices and Circuits, J. Millman and C. C. Halkias and S. Jit (4th Ed., McGraw-Hill, 2015)
3. Measurement, Instrumentation and Experimental Design in Physics and Engineering, M. Sayer and A. Mansingh (Prentice Hall India, 2010)

Nuclear Physics:

4. Radiation Detection and Measurement, G. F. Knoll (3rd Ed, John Wiley & Sons, Inc, 2000).
5. Physics & Engineering of Radiation Detection, S. N. Ahmed (Academic Press 2007)
6. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (Springer Verlag 1987).

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-DSE4112

Course Name: Experimental Laboratory in Materials and Optical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Experimental Laboratory in Materials and Optical Physics DSE	4	0	0	4	

Duration: 120 hours (8P/Week)

Course Objective:

The major objective of this course is to revise the basic concepts of electronics/nuclear physics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Contents:

Solid State Physics

Unit I- Experimental Techniques

- Production and measurement of low pressures.
- Production and measurement of high pressures.
- Measurement and control of low temperatures.
- Production and characterization of plasma.
- Electron Spin Resonance.
- Nuclear Magnetic Resonance.

Unit II- Electrical Transport Properties

- Measurement of resistivity – Four probe and van der Paw techniques; determination of band gap.
- Measurement of Hall coefficient – determination of carrier concentration.
- Measurement of magneto resistance.
- Measurement of thermoelectric power.
- Measurement of minority carrier lifetime in semiconductors Hyne Shockley experiment.

Phase Transitions and Crystal Structure

- Phase Transitions and Crystal Structure: Determination of transition temperature in ferrites.
- Determination of transition temperature in ferroelectrics.
- Determination of transition temperature in high Tc superconductors.

- Determination of transition temperature in liquid crystalline materials.
- Crystal structure determination by x-ray diffraction powder photograph method.

Unit III - : **Waves and Optics**

- Velocity of sound in air by CRO method.
- Velocity of sound in liquids – Ultrasonic Interferometer method.
- Velocity of sound in solids – pulse echo method.
- Propagation of EM waves in a transmission line – Lecher wire.
- Determination of Planck's constant.
- Jamin's interferometer – refractive index of air.
- Study of elliptically polarized light.

Unit IV-:

Optical Spectroscopy

- Constant deviation spectrometer-fine structure of Hg spectral lines.
- e/m or hyperfine structure using Febry Perot's interferometer.
- Band spectrum in liquids.
- Raman scattering using a laser source.
- Luminescence.

Laser Based Experiments

- Optical interference and diffraction.
- Holography.
- Electro-optic modulation.
- Magneto-optic modulation.
- Acousto-optic modulation.
- Sound modulation of carrier waves.

NOTE:

The list of experiments given above should be considered as suggestive of the standard and available equipment. The teachers are authorized to add or delete from this list whenever considered necessary.

Course Learning Outcomes

At the end of this laboratory course, each and every student is expected to understand the basic concepts of electronics/nuclear physics through experiments, which would immensely help them in acquiring knowledge to tackle various competitive exam questions.

Suggested Readings

Solid State Physics

1. Introduction to Solid State Physics: Charles Kittel, 8th edition (John Wiley and Sons, inc, 2005).
2. Physics of Semiconductor devices S.M. Sze (Wiley, 2006).

Waves and Optics:

1. Lasers: Fundamental and Applications, Graduate Text in Physics, 2nd edition, K. Thyagarajan, Ajoy Ghatak (Springer, 2002).
2. Polarization of light, by Ajoy Ghatak and Arun Kumar (Mc GrawHill Education, 2012).
3. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000).
4. Teaching laser physics by experiments, Am. J. Phys., (2011), http://doi.org/1-3488984 .

MASTER of SCIENCE in PHYSICS
Semester I
Course Code: PH-DSE4113
Course Name: Mathematical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Mathematical Physics DSE	4	3	1	0	

Duration: 60 hours (45L+ 15T)

Course Objectives

The primary objective is to teach the students basic mathematical methods that will be used in many of the other courses in the M.Sc. Syllabus.

Contents:

Unit I (12 hours)

Linear Vector Space: A brief review of linear vector spaces, Inner product, norm, Schwarz inequality, Gram-Schmidt Orthogonalization, linear operators, eigenvalue and eigenvector, adjoint operator, Hermitian or self-adjoint operators and their properties, unitary operators, orthonormal basis–discrete and continuous.

Unit II (10 hours)

Theory of Probability and Statistics: Random Variables, Binomial, Poisson and Normal Distributions. Central Limit Theorem, Hypothesis Testing and Data Analysis in Statistics.

Unit III (8 hours)

Complex Analysis: Complex Analysis including use of residue theorem. Integral Transforms, Green's functions.

Unit IV (15 hours)

Discrete Group Theory: Abstract groups: subgroups, classes, cosets, factor groups, normal subgroups, cyclic, permutation, direct product of groups; Homomorphism & isomorphism. Representations: reducible and irreducible, unitary representations, Schur's lemma and orthogonality theorems, characters of representation, direct product of representations.

Course Learning Outcomes

Students will learn the required Mathematics techniques that may have not been covered in the courses in B.Sc. CBCS program and which will be useful in many other courses in M.Sc.

Suggested Readings

1. Mathematical Physics, V. Balakrishnan (Ane Books, 2018).
2. Mathematical Methods for Physicists, G. Arfken (Elsevier, 2012).

3. Advanced Engineering Mathematics, E. Kreyzig (Pearson, 2002.
4. Elements of Group Theory for Physicists, A.W. Joshi (John Wiley, 1997).
5. Groups and Symmetry, M. A. Armstrong(Springer, 1988).
6. Introductory Statistics, S. M. Ross (Academic Press Inc., 2005).
7. Elements of Group Theory for Physicists, AW Joshi (New Age International Private Limited, 2018).

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-DSE4114

Course Name: Relativistic Dynamics and Applications

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Relativistic Dynamics and Applications DSE	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

To develop a conceptual and mathematical understanding of the Special theory of Relativity and relativistic particle dynamics and fields, providing students substantial aptitude and familiarity with Lorentz transformations, the Lightcone structure of the Minkowski space-time, vectors and tensors in the Minkowski space-time, both from the theoretical perspective and in applied contexts, such as in the particle collision and decay problems.

Unit I: Foundations of Special Relativity: (12 hours)

Fallout of Galilean Relativity: confrontation with Maxwell's electrodynamics. Postulates of Special Relativity. Lorentz and Poincaré transformations. Rotations, boosts and the invariant line element. Lorentz transformations for single and multiple boost(s). Lorentz transformations as hyperbolic rotations: rapidity. Successive Lorentz boosts and relativistic velocity addition. Thomas precession. Lorentz and Poincaré groups. Proper and improper Lorentz transformations. Representations of the infinitesimal Lorentz group.

Unit II: Schematic Illustration of Relativistic Space-times: (9 hours)

Minkowski space-time diagrams. Worldlines and coordinates of events. Simultaneity lines, rapidity angle and the Lightcone. Temporal ordering of events, super-luminal signals and causality. Space-time intervals – space-like, time-like and null. Proper time and time dilation. Length contraction. Relativistic Doppler effect. Illustrations of the twin paradox, train-rain paradox, etc using the Minkowski diagrams.

Unit III: Vectors and Tensors in Special Relativity (9 hours)

Rules of transformation of coordinate differentials and derivatives. Inverse transformations. Internal transformations: polar and axial vectors. Tensors: definition, categorization, covariance and contravariance, properties and operations, norm and trace. Properties and application of the metric tensor and the Minkowski metric. Symmetry, antisymmetry, symmetrization and antisymmetrization of tensors. Levi-Civita and the generalized Kronecker delta tensors. Tensor duality. Tensor calculus: gradient; divergence; curl and the D'Alembertian, the invariant four volume and tensor integration.

Unit IV: Relativistic Particle Dynamics, Relativistic Fields and Systems (15 hours)

Four-velocity and four-acceleration. Four-momentum and energy. Mass-energy equivalence and the energy-momentum conservation. Illustrative examples: Compton effect, particle collision and decay, two-body interactions and scattering in laboratory and center-of-mass frames. Proper acceleration and four-force. Least action principle for relativistic particles. Covariant Lagrangian and Hamiltonian. Energy-momentum tensor. Applicable systems: real and complex scalar fields, relativistic vector fields and charge/current distributions, relativistic perfect fluids.

Course Learning Outcomes

By the end of this course, the students can understand and apply special relativity and Lorentz transformations to physical phenomena using Minkowski spacetime diagrams and relativistic kinematics, work with tensors, analyze the dynamics pertaining to relativistic interactions such as Compton scattering and particle decays, develop substantial skill in using relativistic approaches for specific systems of particles and fields, which would be useful for many other M.Sc. courses.

Suggested Reading:

1. The Classical Theory of Fields (Course of Theoretical Physics Series), L.D. Landau, E.M. Lifshitz (4th Edition, Volume 2, Butterworth-Heinemann, Elsevier, 1975).
2. Classical Mechanics, Herbert Goldstein, Charles P. Poole, John L. Safko (3rd Edition, Addison-Wesley, 2002).
3. Introduction to Special Relativity, Robert Resnick (John Wiley & Sons, 1968).
4. Introduction to Special Relativity, Wolfgang Rindler (2nd Edition, Oxford, 1991).
5. Gravitation and Cosmology, Steven Weinberg (John Wiley & Sons, 1972).

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-DSE4115

Course Name: Experimental Technique in Nuclear Science

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Experimental Technique in Nuclear Science DSE	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objective

To provide a comprehensive understanding of the principles of radioactivity and nuclear decay processes required for experiments performed at the laboratory. To familiarize students with the interaction of nuclear radiation with matter and the mechanisms involved. To introduce various radiation detectors, counting techniques, and statistical methods used in nuclear experiments. To equip students with foundational knowledge of signal processing and applications of nuclear radiation in diverse fields.

Content

Unit I (10 hours)

Radioactivity: Introduction to Radioactivity, Decay Law, Units and Production of radioactivity, Radioactive sources, Growth of Daughter activities, , Branching Ratios, Half-life and mean life, Nuclear Decay processes, Decay Equation, Decay Schemes, Alpha Decay: alpha decay energies, qualitative theory of alpha decay and alpha-ray spectra, Beta Decay: Beta spectrum, Gamma Decay: Energetics and spectrum, Semiempirical Mass Formula, Q-value of Decay and reactions.

Unit II (10 hours)

Interaction of Radiation with Matter: Interaction of light charged particles with matter, Ionization, Bragg Curve and Bragg Peak, Range and Energy Relation, Radiation length and straggling, Interaction of Gamma Radiation with Matter: Attenuation of Gamma rays, Compton Effect, Photoelectric Effect and Pair Production, Attenuation and absorption Coefficients.

Unit III (12 hours)

Radiation Detectors and Counting Statistics: Classification, Gas-filled Detectors: Ionisation, Proportional and Geiger-Muller Counters; Concept of Multiplication, Quenching, and Dead Time. Brief introduction of scintillators and semiconductor detectors,

Types of uncertainties in a measurement, Probability and Cumulative distribution function, variance and standard deviation; Binomial, Poisson and Gaussian distribution, Error Propagation

Unit IV (13 hours)

Basics of Signal Processing: Basic electronic circuits for signal processing (GM and Scintillator detectors), Logic standard, Pulse shaping and digital signal processing for energy, time and position measurement, Digital Oscilloscope.

Application of Nuclear Radiation in Medicine, Industry, Research, Security, Agriculture and Space.

Learning outcome

After successful completion of the course, students will be able to: Understand and explain the physical principles governing radioactive decay and nuclear interactions. Analyze the behavior of nuclear radiation as it passes through matter and interpret relevant parameters such as range, attenuation, and energy loss. Select and apply appropriate radiation detection techniques and interpret experimental data using statistical analysis. Demonstrate an understanding of signal processing techniques and recognize real-world applications of nuclear science in medicine, industry, and other sectors.

Suggested Readings:

1. Radiation Detection and Measurement by G. F. Knoll (3rd Ed. John Wiley & Sons, Inc.,2000)
2. Physics & Engineering of Radiation Detection by S. N. Ahmed (Academic Press 2007)
3. Techniques for Nuclear and Particle Physics Experiments by W.R. Leo (Springer-Verlag 1987)
4. Nuclear Physics, Principles and Applications by J.S. Lilly (John Wiley & Sons, Inc., 2002).
5. Radiation Detection: Concept, Method and Devices by Douglas S. McGregor and J. Kenneth Shultis, (Taylor and Francis 2020)

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-ET4116

Course Name: Materials Characterization Techniques

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Materials Characterization Techniques DSE	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives:

This course intends to provide knowledge on the advanced characterization techniques used to identify the physical and chemical properties of new materials prepared in laboratories. This includes, materials, electrical, optical, magnetic, and dielectric properties of materials and their specific applications. The students will have the experience of different characterization techniques used in experimental condensed matter physics with the available theories, operation, and instrumentation.

Unit I (8 hours)

Structure analysis: X-ray diffraction (XRD): Basic principle, Fourier analysis of the basis, structure factor and atomic form factor, indexing and lattice parameter determination, features of XRD experiment, film negative and Straumannis chamber, powder method, Laue method, information from peak position, intensity and width of XRD pattern. Crystal size and microstrain determination by Scherrer, modified Scherrer and Williamson-Hall methods.

Unit II (18 hours)

Imaging Techniques - Optical and electron microscopies, Electron Beam – Specimen Interaction, Secondary and Backscattered electrons, Interaction cross-section and volume, Scanning electron microscope (SEM), operational systems of SEM instrumentation and imaging modes, energy dispersive X-ray spectroscopy, transmission electron microscope, selected area electron diffraction, pattern writing using optical and electron beams.

Spectroscopies: Characterization of fluorescence emission, Jablonski diagram, fluorescence quantum yield and life time, instrumentation for fluorescence spectroscopy, absorption and photoluminescence spectroscopy, Tauk plot, energy band gap determination, Raman spectroscopy, Fourier transform infrared spectroscopy, X-ray photoemission spectroscopy, X-ray absorption spectroscopy, Nuclear magnetic resonance (NMR) spectroscopy.

Unit III (14 hours)

Surface Morphology and Topography, scanning probe microscopy, scanning tunneling microscope (STM), atomic force microscope (AFM), concept and modes of operation of STM and AFM, conducting AFM.

Rutherford backscattering spectrometry, scattering geometry and kinematic factor, scattering cross-section, energy loss and stopping cross section, energy straggling, surface impurity on an elemental bulk target, Thermogravimetric analysis and differential thermal analysis: principle and instrumentation, differential scanning calorimetry.

Unit IV (5 hours)

Physical Properties: Electrical measurements: Resistivity, temperature dependence of resistivity in materials, resistance in bulk and low-dimensional systems, Current voltage characteristics, estimation of resistivity using four probe Van-der Pauw methods.

Dielectric and magnetic measurements: Frequency dependence on capacitance-voltage characteristics, estimation of dielectric constant. diamagnetics, paramagnetics, feromagnetics, B-H loop, operation and analysis of vibrating-sample magnetometry, ferroelectrics, polarization-electric field loop.

Course Learning Outcomes:

The students should able to experience the advanced characterization techniques pursued in the experimental condensed matter physics for studying the physical properties of the materials in the semiconductor technologies and nanotechnology.

Suggested readings:

1) X–Ray Crystallography by M. J. Buerger: Wiley–Blackwell; 99th ed. edition (January 1966)
2) Elements of X-ray Diffraction by B. D. Cullity: Addison-Wesley Publishing Company Inc. (1978)
3) Analytical Electron Microscopy for Materials Science by D. Shindo and T. Oikawa, Springer Verlag, Japan; 2002nd edition
4) Handbook of Spectroscopy edited by Günter Gauglitz, Tuan Vo-Dinh: WILEY-VCH Verla GmbH & Co, 2003
5) Scanning Probe Microscopy: Atomic Force Microscopy and Scanning Tunneling Microscopy by Bert Voigtländer, Springer-Verlag Berlin Heidelberg, 2015

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-DSE4117

Course Name: Technique in Theoretical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Technique in Theoretical Physics DSE	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

The course will introduce to the students' basic concepts of finite and infinite groups. Examples from various fields will be considered. Techniques for solving integral equations will be learnt. Introduction to Green functions and its construction will be studied.

Contents:

Unit I (10 hours)

Introduction of finite discrete Group: subgroups, classes, cosets, factor groups, normal subgroups, direct product of groups; Examples: cyclic, symmetric, matrix groups, regular n-gon. Mappings: homomorphism, isomorphism, automorphism. Representations: reducible and irreducible representation, unitary representations, Schur's lemma and orthogonality theorems, characters of representation, direct product of representations.

Unit II (15 hours)

Continuous Group: Review of the continuous groups: Lie groups, rotation and unitary groups. Representation of SO(2), SO(3), SU(2), SU(3), Tensors. Applications: point groups, translation and space groups, representation of point groups; introduction to symmetry group of the Hamiltonian.

Unit III (10 hours)

Integral Equations: Conversion of ordinary differential equations into integral equations, Fredholm and Volterra integral equations, separable kernels, Fredholm theory, eigen values and eigen functions.

Unit IV (10 hours)

Green function: Boundary Value Problems: boundary conditions: Dirichlet and Neumann; self-adjoint operators, Sturm-Liouville theory, Green's function, eigenfunction expansion.

Course Learning Outcomes

The understanding of the classification of finite groups will be achieved. Upon completion of this course, students should be able to use these concepts in various fields, particularity in crystallography. Students will be able to learn the different analytical techniques for solving integral equations and construct Green's functions for many important boundary value problems.

Suggested Readings:

1. Elements of Group Theory for Physicists, A.W. Joshi (John Wiley, 1997).
2. Groups and Symmetry,M. A. Armstrong(Springer, 1988).
3. Advanced Method of Mathematical Physics, R. S. Kaushal & D. Parashar (Narosa, 2008).
4. Group Theory and Its Applications to Physical Problems, M. Hamermesh (Dover, 1989).
5. Chemical Applications of Group Theory, F. Albert Cotton (John Wiley, 1988).
6. Mathematical Methods for Physicists,G. Arfken, H. Weber, & F. Harris (Elsevier, 2012).
7. Linear Integral Equations, W. V. Lovitt (Dover, 2005).
8. Introduction to Integral Equations with Applications, A. J. Jerri (Wiley-Interscience, 1999).

MASTER of SCIENCE in PHYSICS
Semester I
Course Code: PH-SBC4171
Course Name: Workshop skills

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Workshop skills SBC	2	0	0	2	

Duration: 60 hours

Course objective:
The aim is to teach them how to handle machines which can be useful for precise cutting in lab accessories useful for experiments.

Content:
Hands-on experience:
Unit-I:
- Lathe machine (Plane turning, step turning, taper turning)
- Drill machine

Unit-II:
- Plate cutting
- Hand tools (hacksaw, drilling, tapping, filing)

Learning outcome:
The student will be confident and skilled for handling lab useables and small repairs.
(Not more than seven students at a time due to space constraints and safety.)

MASTER of SCIENCE in PHYSICS

Semester I
Course Code: PH-SBC4172

Course Name: Python for Physicists

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Python for Physicists SBC	2	0	0	2	

Duration: 60 hours

Course Objective:
This course is intended to be an Introduction to a programming Language (Python) for physics students. The course would impart training in the structure of Python and basic applications.

Content:
Unit-I:
- Basic Python (loops, mathematical and logical operations), Arrays, numpy, and reading and writing to files.
- Matrices, Matrix algebra, eigenvalue , eigenvector .

Unit-II:
- Basic plotting using Gnuplot and Python
- Simple applications: series, summation, root finding

Course Learning Outcomes
A student having taken the course would be expected to be proficient in programming in the language (Python). In addition, it is also expected that the student would be able to use Python
to solve problems of summing up infinite series, root finding.

Suggested reading:
1. Lab manual for Python for Physicists, Department of Physics and Astrophysics, University of Delhi, 2025.
2. https://www.python.org/doc/
3. Numerical Recipes in C: The Art of Scientific Computing, William H. Press, Brian P. Flannery, Saul A. Teukolsky, William T. Vetterling (2nd Ed., Cambridge University Press, 2002)

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-SBC4173

Course Name: Radiation Safety

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Radiation Safety SBC	2	1	0	1	

Duration: 45 hours (15T+30P)

Course Objectives

The primary objective of this course is to provide students with a comprehensive understanding of radiation fundamentals, interaction mechanisms, detection principles, dosimetric techniques, and regulatory frameworks associated with radiation safety and protection. Through theoretical instruction and practical demonstrations, students will gain both conceptual and operational knowledge required for safe handling, measurement, and monitoring of ionizing radiation, along with a sound understanding of national guidelines and protocols for radiation protection and waste management.

Contents:

Unit I (15 hours)

Basics of Radiation: Origin of radiation, binding energy and Q-value, stable and unstable isotopes, radioactive decay (alpha, beta, neutron, and electromagnetic transitions), mean life and half life, Basic idea of different units of activity, radiation quantities; exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, quality factor, radiation and tissue weighting factors, committed equivalent dose, committed effective, radiation dose to individuals from natural radioactivity in the environment and man-made sources

Devices for radiation measurement and survey: Radiation interaction with matter, kinematics of nuclear reactions, slowing down and moderation of neutrons, Interaction of ionizing and non-ionising radiation at the cellular level. introduction to types of radiation detectors; semiconductor, scintillator and gas detectors(Geiger-Muller counters, ionisation chamber and proportional counters). principles of radiation counting statistics, dead time, and calibration standards. types of Radiation Dosimeters: thermoluminescence, radiographic films, calorimetry, semiconductor diodes; Relation between detection and dosimetry.

Regulatory Framework: classification of radioactive sources (A/D classification), the system of radiological protection, justification of practice, optimization of protection, and individual limits, categories of exposures-occupational, public, and medical exposures, evaluation of external Radiation hazard-effect of distance, time, and shielding, shielding calculation; internal radiation hazards. Personnel and area monitoring, radiation accidents and disaster monitoring, Radioactive waste & classification of Radioactive waste, transport of radioactive sources/waste, responsibilities of licensee regulatory bodies AERB, and the government.

Unit II (30 hours)

Suggested Exercises / Practical Demonstrations

1) Demonstration handling of radiation monitor and survey instruments.
2) Demonstration of Distance, Time, and shielding concept of the ALARA principle.
3) Demonstration of the Search and Secure procedure for handling radioactive sources
4) Measurement of the activity of an unknown radioactive source.
5) Radiation Protection Survey of a Radioisotope Laboratory
6) Contamination Measurement and Decontamination Procedures
7) Calibrate radiation monitors using standard radioactive sources.
8) Classification of Radiation facility using AERB guidelines.
9) Packing classification and Transport Index (TI) for radioactive isotope/waste transport.

Course Learning Outcomes

A sound understanding of the principles underlying the operation of various radiation detectors, the calculation of radiation doses and permissible exposure levels for different categories of users, the effects of radiation, the use of instrumentation in practical scenarios, proper management of radioactive materials, and strict adherence to safety protocols.

Suggested Readings

1. Nuclear and Particle Physics, W. E. Burcham and M. Jobes (Pearson Education, 1995)
2. Radiation detection and measurement, G. F. Knoll (4^{th} Ed., Wiley, 2010)
3. Thermoluminescence Dosimetry, Mcknlay, A. F., Bristol, Adam Hilger (Medical Physics Hand book 5)
4. Fundamental Physics of Radiology, W. J. Meredith and J. B. Massey (John Wright and Sons, 1989)
5. An Introduction to Radiation Protection, A. Martin and S. A. Harbisor (John Willey & Sons, 1981)
6. Medical Radiation Physics, W. R. Hendee (Medical Publishers Inc., 1981)
7. Nuclear Physics : Principles and applications, John Lilley (Wiley, 2001)
8. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (2^{nd} Ed., Elsevier, 2014)
9. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (2^{nd} Ed., Springer, 2013)
10. AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities.
11. AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources.

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-SBC4174

Course Name: Order of Magnitude Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Order of Magnitude Physics SBC	2	1	0	1	

Duration: 45 hours (15L+30P)

Course Objectives

Often before doing a detailed theoretical calculation or prior to setting up an experiment to measure an effect, One needs to have a rough idea as to weather or not our set up or the calculation is likely to give a meaning result and weather spending efforts time and funds are worth it. It is in this context that this course is significant. The objective of this course is to train students to make estimates without having to do a detailed calculation or experiment to get a rough idea of how the results could look.

Course Contents

(Including Demonstration/Practical)

Unit I : (25 hours)

- **Estimation of Physical quantities using Dimensional Analysis.**

Dimensional analysis in Mechanics: Damping in a pendulum, Free Gravitational collapse of a dust sphere, Oscillation time period of a star, Time taken for photon to diffuse out of sun, Dimensional analysis in Fluid Mechanics: Reynolds', Froude and Strouhaul numbers in Fluids, terminal velocity

- **Scaling analysis in Classical Physics**

Orbital time period vs Orbital size of planets, Dynamics in a power law potential, Estimating the acceleration due to gravity on the surface of the moon, How high can an animal jump? Orbital time of planets, Scale height of the Atmosphere

Unit II : (20 hours)

- **Application to different areas in Physics.**

Electrodynamics. Quantum Physics, Waves, Materials

- **Applications to Integrals and differential equations:**

Estimating integrals, steepest descent approximation. Approximate solutions to differential equations.

Course Learning Outcomes

Students will come away from the course with an appreciation of the characteristic scales associated to a physical system, and how to use simple approximate models to estimate a variety of quantities of physical interest. They will also learn approximation techniques for integrals and differential equations.

Suggested Reading

1. Peter Goldreich, Sanjoy Mahajan and Sterl Phinney - Order of Magnitude Physics.
2. Sanjoy Mahajan - Estimating gas mileage: An example of order-of-magnitude physics (arXiv:physics0512209)
3. Steven Doty and Sandra Doty, Dielectric breakdown of air as order of magnitude physics (Physics teacher Volume 36, Pages 6-9, 1998)

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-SBC4175

Course Name: Strategies for Scientific Dialogue in Research

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Strategies for Scientific Dialogue in Research SBC	2	1	0	1	

Duration: 45 hours (15L+30P)

Course Objectives:

The course is designed to develop and strengthen students' ability to communicate scientific ideas clearly and effectively, both in written and oral formats. It aims to expose students to cutting-edge research through seminars delivered by faculty members and invited experts. Emphasis is placed on cultivating skills in scientific literature review, critical analysis, and academic discourse. The course also prepares students for academic presentations, thesis defenses, and professional scientific interactions. Recognizing that many students produce excellent research but struggle to present it effectively, this course seeks to bridge that crucial gap.

Course Learning Outcomes:

Upon successful completion of the course, students will be able to: Comprehend and effectively communicate recent research developments in physics and allied disciplines. Summarize and synthesize scientific literature with clarity, coherence, and critical insight. Prepare and deliver well-structured, confident, and audience-appropriate scientific presentations. Engage thoughtfully in scholarly discussions and respond competently to academic queries.

This course will be particularly beneficial for students planning to undertake project work or a dissertation in the third and fourth semesters.

Course Structure and Activities:

UNIT -I (15 hours)

Lecture Attendance & Research Exposure:

➢ Students must attend a minimum of 10 research lectures organized by the department. These may include:
   1. Presentations by department faculty on their current research.
   2. Lectures by invited national or international experts.

- ➢ Students will submit comprehensive summaries (approx. 400–500 words) of at least five selected lectures, highlighting key concepts, methods, and findings.

UNIT -II (30 hours)

Seminar Preparation and Delivery (20 Hours):

- ➢ Students will be assigned a research topic or paper, drawn from current research themes or courses offered in the M.Sc. syllabus.
- ➢ They will receive study materials, including relevant papers, reviews, or resources from the faculty.
- ➢ Each student must prepare a written synopsis (~800–1000 words) on the assigned topic.
- ➢ Students will then present a seminar (15–20 minutes) based on their understanding, followed by a Q&A session.

The course is structured in the spirit of a Dissertation under the DSE category, but with lower credit weightage and, accordingly, reduced academic rigor. As such, the number of hours assigned is indicative rather than prescriptive, intended to reflect the approximate level of effort expected.

Assessment and Evaluation:

Component

i) Participation in Departmental Lectures
ii) Written Summaries of Attended Lectures
iii) Written Review of Assigned Research Topic
iv) Seminar Presentation (Content, Clarity, Delivery)

The Evaluation will be conducted by:

i) A three-member departmental committee for the overall course.
ii) A two-member subcommittee for seminar presentation evaluation.

Notes for Implementation:

- ➢ Attendance at department seminars will be tracked.
- ➢ Students may optionally include key questions or insights from each attended lecture.
- ➢ Emphasis will be placed on communication skills, depth of understanding, organization of content, and response to questions.
- ➢ This course encourages peer learning and academic engagement beyond the classroom.

MASTER of SCIENCE in PHYSICS
Semester II
Course Code: PH-DSC4201
Course Name: Quantum Mechanics-II

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Mechanics-II DSC	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

The primary objective is to teach the students various approximation methods in quantum mechanics. The important topic of quantum scattering is also dealt with. Also some aspects of non-Hermitian systems and Relativistic quantum theory, such as the Dirac equations, are covered.

Contents:

Unit I (13 hours)

WKB method, hydrogen-like atoms, and spherical harmonics. Spin-half particle: nonrelativistic (Pauli theory) and relativistic (Dirac equation and plane wave solution), Addition of angular momenta. Clebsch-Gordan coefficients, Wigner-Eckart theorem, application of approximate methods.

Unit II (13 hours)

Approximation Methods for time-dependent perturbations: Interaction picture. Time-dependent perturbation theory. Transition to a continuum of final states – Fermi's Golden Rule. Application to constant and harmonic perturbations, sudden and adiabatic Approximations.

Unit III (12 hours)

Scattering: Wave packet description of scattering. Lippmann-Schwinger Equations, Formal treatment of scattering by Green's function method. Born approximation and applications. Definition and properties of S-Matrix Partial wave analysis. Optical theorem.

Unit IV (7 hours)

Introduction to non-Hermitian systems: energy eigenvalues, eigenvectors and their spectral properties, exceptional points, PT symmetric systems.

Course Learning Outcomes

Students will learn how to use perturbation theory to obtain corrections to energy eigenstates and eigenvalues when an external electric or magnetic field is applied to a system. Scattering theory will teach them how to use projectiles to infer details about the target quantum system. Exposer to Dirac's equation and non-hermitian systems.

Suggested Readings:

1. Quantum Mechanics, L.I. Schiff, McGraw-Hill,2017
2. Principles of Quantum Mechanics, R. Shankar, Springer,2011
3. Introduction to Quantum Mechanics, D.J. Griffiths, Cambridge University Press, 2018
4. A Modern Approach to Quantum Mechanics, J.S. Townsend, Viva Books
5. E. Merzbacher, Quantum Mechanics, John Wiley and Sons
6. F. Schwabl, Advanced Quantum Mechanics, Springer
7. A. Das, Hours on Quantum Mechanics, Hindustan Book Agency
8. M. Le Bellac, Quantum Physics, Cambridge University Press
9. J. J. Sakurai, Modern Quantum Mechanics, Pearson
10. S. Flügge, Practical Quantum Mechanics, Springer
11. K. Gottfried and T.-M. Yan, Quantum Mechanics: Fundamentals, Springer
12. R.P. Feynman, Feynman Hours on Physics (Vol. III), Addison-Wesley
13. C. Cohen-Tannoudji, B. Diu and F. Laloe, Quantum Mechanics (Vols. I and II),Wiley
14. A. Messiah, *Quantum Mechanics (Vols. I and II)*, Dover
15. P. A. M. Dirac, The Principles of Quantum Mechanics (International Series of Monographs on Physics).

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-DSC4202

Course Name: Electromagnetic Theory & Electrodynamics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Electromagnetic Theory & Electrodynamics DSC	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

To develop a conceptual and mathematical basis for Classical Electromagnetism and its Relativistic formulation. The course reviews and builds on the students' knowledge of Special Relativity using Minkowski space-time diagrams and tensorial analysis. While building up the covariant formulation of electrodynamics, this course also provides a detailed account of obtaining the electromagnetic four-potential using Green's functions, the transformation of the electromagnetic field, the study of motion of relativistic charges in electric and magnetic fields, as well as radiation from moving point charges and localized time-harmonic distributions.

Contents:

Unit I: Basic electromagnetism, relativistic concepts and covariant electrodynamics (20 hours)

A brief review of basic electromagnetic (EM) theory. Maxwell's equations and the motivation for introducing Special Relativity (SR). Conceptual basis of SR theory: the postulates, Lorentz and Poincaré transformations, the invariant line element, worldlines and coordinates of events, Minkowski space-time diagrams, simultaneity and rapidity, types of space-time intervals, the causal structure of spacetime and the Lightcone. Vectors and tensors in Minkowski space-time. Tensor algebra, symmetry and antisymmetry, duality, differentiation and differential operators. Mass-energy relation, four-momentum and its conservation. Covariant Lorentz force equation. EM field tensor and conserved four-current. Covariance of the Maxwell's equations. EM scalar invariants and the transformation laws. EM four-potential. Gauge invariance of the EM field. Gauge conditions: Coulomb and Lorentz gauges. EM wave equation. Retarded and advanced solutions for the EM four-potential using Green's functions.

Unit II: Relativistic charged particle dynamics (5 hours)

Electric and magnetic fields due to a uniformly moving charged particle. Motion of charged particles in a uniform static magnetic field, uniform static electric field and crossed electric and magnetic fields. Particle drifts (velocity and curvature) in non-uniform static magnetic fields.

Unit III: Electromagnetic Radiation (15 hours)

Radiation from a moving point charge: Lienard-Wiechert potentials and fields, Larmor power formula and its relativistic generalization – the Lienard result, charged particle accelerators, angular distribution of radiation from accelerated charged particles. Radiation from localized time-harmonic charges, currents and their distributions: specification of EM vector potential in the Lorentz gauge, near and far zone fields, multipole expansion, Poynting theorem for a time-harmonic source current. Electric dipole, magnetic dipole and electric quadrupole radiation. Centre-fed linear dipole antenna.

Unit IV: Lagrangian Formulation of Electrodynamics (5 hours)

Lagrangian for a relativistic charged particle in an EM field, for the free electromagnetic field and for interacting charged particles and fields. Energy-momentum tensor and related conservation laws.

Course Learning Outcomes

Students having taken this course are expected to have a fair degree of familiarity with tensors and the tensorial formulation of electrodynamics. In addition, they are expected to be able to solve problems on motion of charged particles in various field formations as well as find the radiation patterns from different time-varying charge and current densities.

Suggested Readings

1. Classical Electrodynamics, John David Jackson (3rd ed.,Wiley, 1998).
2. The Classical Theory of Fields (Course of Theoretical Physics Series, volume 2), L.D. Landau and E.M. Lifshitz (4th ed., Butterworth-Heinemann, Elsevier, 1975).
3. Introduction to Electrodynamics, David J. Griffiths (3rd ed., Benjamin Cummings, 1999).
4. Principles of Electrodynamics, Melvin Schwartz (Dover Publications, 1987).
5. Classical Electrodynamics, J. Schwinger, L.L. Deraad Jr., K.A. Milton, W-Y. Tsai and J. Norton (Westview Press, 1998).
6. Modern Problems in Classical Electrodynamics, Charles A. Brau (Oxford, 2003).
7. Electrodynamics of Continuous Media (Course of Theoretical Physics Series, volume 8), L.D. Landau, L.P. Pitaevskii and E.M. Lifshitz (2nd ed., Butterworth-Heinemann, Elsevier, 1984).

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-DSC4203

Course Name: Solid State Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Solid State Physics DSC	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objective

This course intends to provide knowledge of conceptual solid-state physics. In addition, this course aims to provide a general introduction to theoretical and experimental topics in solid state physics.

Contents:

Unit I (16 hours)

Metals: Drude theory, DC conductivity, magneto-resistance, thermal conductivity, thermoelectric effects, Fermi-Dirac distribution, thermal properties of an electron gas, WiedemannFranz law, critique of free-electron model.

Crystal Lattices: Diffraction of electromagnetic waves by crystals: X-rays, Electrons and Neutrons, Symmetry operations and classification of Bravais lattices, common crystal structures, reciprocal lattice, Brillouin zone, X-ray diffraction, Bragg's law, Von Laue's formulation, diffraction from non-crystalline systems. Geometrical factors of SC, FCC, BCC and diamond lattices; Basis of quasi crystals.

Unit II (8 hours)

Crystal Binding: Bond classifications – types of crystal binding, covalent, molecular and ionic crystals, London theory of van der Waals, hydrogen bonding, cohesive and Madelung energy.

Defects and Diffusion in Solids: Point defects: Frenkel defects, Schottky defects, examples of colour centres, line defects and dislocations.

Unit III (12 hours)

Lattice Dynamics: Failure of the static lattice model, adiabatic and harmonic approximation, vibrations of linear monoatomic lattice, one-dimensional lattice with basis, models of three-dimensional lattices, quantization of lattice vibrations, Einstein and Debye theories of specific heat, phonon density of states, neutron scattering.

Band theory of Solids: Periodic potential and Bloch's theorem, weak potential approximation, density of states in different dimensions, energy gaps, Fermi surface and Brillouin zones. Origin of energy bands and band gaps, effective mass, tight-binding approximation and calculation of simple band-structures. Motion of electrons in lattices, Wave packets of Bloch electrons, semi-classical equations of motion, motion in static electric and magnetic fields, theory of holes, cyclotron resonance.

Unit IV (9 hours)

Semiconductors: General properties and band structure, carrier statistics, impurities, intrinsic and extrinsic semiconductors, drift and diffusion currents, mobility, Hall effect.

Superconductors: Phenomenology, review of basic properties, thermodynamics of superconductors, London's equation and Meissner effect, Type-I and Type-II superconductors, BCS theory of superconductors.

Course Learning Outcomes

The students should be able to elucidate the important features of solid state physics by covering crystal lattices and binding, lattice dynamics, band theory of solids and semiconductors.

Suggested Readings

1. Introduction to Solid State Physics, C. Kittel (8th Ed., Wiley, 2012)
2. Solid State Physics, N. W. Ashcroft and N. D. Mermin (Ist Ed., Cengage Learning, 2003)
3. Principles of the Theory of Solids, J. M. Ziman (2nd Ed., Cambridge University Press, 1972)
4. Solid State Physics, A. J. Dekker (1st Ed., Macmillan India, 2000)
5. Solid State Physics, G. Burns (1st Ed., Academic Press, 1985)
6. Condensed Matter Physics, M. P. Marder (Wiley, 2010)

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-DSE4211

Course Name: Foundational Laboratory in Experimental Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Foundational Laboratory in Experimental Physics DSE	4	0	0	4	

Duration: 120 hours (8P/Week)

Course Objective

The major objective of this course is to revise the basic concepts of electronics/nuclear physics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Contents:

Electronics

Unit I-

Device Characteristics and Application

1. p-n junction diodes-clipping and clamping circuits.
2. FET – characteristics, biasing and its applications as an amplifier.
3. MOSFET – characteristics, biasing and its applications as an amplifier.
4. UJT – characteristics, and its application as a relaxation oscillator.
5. SCR – Characteristics and its application as a switching device.

Unit II-

- Linear Circuits

1. Resonant circuits.
2. Filters-passive and active, all pass (phase shifters).
3. Power supply-regulation and stabilization.
4. Oscillator design and study.
5. Multi-stage and tuned amplifiers.
6. Multivibrators-astable, monostable and bistable with applications.
7. Design and study of a triangular wave generator.
8. Design and study of sample and hold circuits.

- Digital Circuits and Microprocessors

1. Combinational.
2. Sequential.
3. A/D and D/A converters.

4. Digital Modulation.
5. Microprocessor application.

Nuclear Physics

Unit III-

Detectors

1. G.M. Counters – characteristics, dead time and counting statistics
2. Spark counter-characteristics and range of x-particles in air
3. Scintillation detector-energy calibration, resolution and determination of gamma ray energy
4. Solid State detector – surface barrier detector, its characteristics and applications.

Unit IV-

- Applications

1. Gamma ray absorption-half thickness in lead for 60Co gamma-rays.
2. Beta ray absorption – end point energy of beta particles.
3. Lifetime of a short lived radioactive source..

- High Energy Physics

1. Study of pi-mu-e decay in nuclear emulsions.
2. Study of high energy interactions in nuclear emulsions.

Course Learning Outcomes

At the end of this laboratory course, each and every student is expected to understand the basic concepts of electronics/nuclear physics through experiments, which would immensely help them in acquiring knowledge to tackle various competitive exam questions.

Suggested Readings

Electronics:

1. Electronic Instrumentation and Measurement Techniques, W. D. Cooper and A. D. Helfrick (2nd Ed., Phi Learning, 2008)
2. Electronic Devices and Circuits, J. Millman and C. C. Halkias and S. Jit (4th Ed., McGraw-Hill, 2015)
3. Measurement, Instrumentation and Experimental Design in Physics and Engineering, M. Sayer and A. Mansingh (Prentice Hall India, 2010)

Nuclear Physics:

4. Radiation Detection and Measurement, G. F. Knoll (3rd Ed, John Wiley & Sons, Inc, 2000)
5. Physics & Engineering of Radiation Detection, S. N. Ahmed (Academic Press 2007)
6. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (Springer Verlag 1987)

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-DSE4212

Course Name: Experimental Laboratory in Materials and Optical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Experimental Laboratory in Materials and Optical Physics DSE	4	0	0	4	

Duration: 120 hours (8P/Week)

Course Objective:

The major objective of this course is to revise the basic concepts of electronics/nuclear physics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Contents:

Solid State Physics

Unit I-

Experimental Techniques

- Production and measurement of low pressures.
- Production and measurement of high pressures.
- Measurement and control of low temperatures.
- Production and characterization of plasma.
- Electron Spin Resonance.
- Nuclear Magnetic Resonance.

Unit II-

Electrical Transport Properties

- Measurement of resistivity – Four probe and van der Paw techniques; determination of band gap.
- Measurement of Hall coefficient – determination of carrier concentration.
- Measurement of magneto resistance.
- Measurement of thermoelectric power.
- Measurement of minority carrier lifetime in semiconductors Hyne Shockley experiment.

Phase Transitions and Crystal Structure

- Phase Transitions and Crystal Structure: Determination of transition temperature in ferrites.
- Determination of transition temperature in ferroelectrics.

- Determination of transition temperature in high Tc superconductors.
- Determination of transition temperature in liquid crystalline materials.
- Crystal structure determination by x-ray diffraction powder photograph method.

Waves and Optics

Unit III -

- Velocity of sound in air by CRO method.
- Velocity of sound in liquids – Ultrasonic Interferometer method.
- Velocity of sound in solids – pulse echo method.
- Propagation of EM waves in a transmission line – Lecher wire.
- Determination of Planck's constant.
- Jamin's interferometer – refractive index of air.
- Study of elliptically polarized light.

Unit IV-:

Optical Spectroscopy

- Constant deviation spectrometer-fine structure of Hg spectral lines.
- e/m or hyperfine structure using Febry Perot's interferometer.
- Band spectrum in liquids.
- Raman scattering using a laser source.
- Luminescence.

Laser Based Experiments

- Optical interference and diffraction.
- Holography.
- Electro-optic modulation.
- Magneto-optic modulation.
- Acousto-optic modulation.
- Sound modulation of carrier waves.

NOTE:

The list of experiments given above should be considered as suggestive of the standard and available equipment. The teachers are authorized to add or delete from this list whenever considered necessary.

Course Learning Outcomes

At the end of this laboratory course, each and every student is expected to understand the basic concepts of electronics/nuclear physics through experiments, which would immensely help them in acquiring knowledge to tackle various competitive exam questions.

Suggested Readings

Solid State Physics

1. Introduction to Solid State Physics: Charles Kittel, 8th edition (John Wiley and Sons, inc, 2005)

2. Physics of Semiconductor devices S.M. Sze (Wiley, 2006)

Waves and Optics:

3. Lasers: Fundamental and Applications, Graduate Text in Physics, 2nd edition, K. Thyagarajan, Ajoy Ghatak (Springer, 2002)
4. Polarization of light, by Ajoy Ghatak and Arun Kumar (Mc GrawHill Education, 2012)
5. Introduction to Fibre Optics, Ajoy Ghatak and K. Thyagarajan, (Cambridge University Press, 2000)
6. Teaching laser physics by experiments, Am. J. Phys., (2011), http://doi.org/1- 3488984

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-DSE4213

Course Name: Material Characterization Techniques

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Materials Characterization Techniques DSE	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives:

This course intends to provide knowledge on the advanced characterization techniques used to identify the physical and chemical properties of new materials prepared in laboratories. This includes, materials, electrical, optical, magnetic, and dielectric properties of materials and their specific applications. The students will have the experience of different characterization techniques used in experimental condensed matter physics with the available theories, operation, and instrumentation.

Unit I (8 hours)

Structure analysis: X-ray diffraction (XRD): Basic principle, Fourier analysis of the basis, structure factor and atomic form factor, indexing and lattice parameter determination, features of XRD experiment, film negative and Straumannis chamber, powder method, Laue method, information from peak position, intensity and width of XRD pattern. Crystal size and microstrain determination by Scherrer, modified Scherrer and Williamson-Hall methods.

Unit II (18 hours)

Imaging Techniques - Optical and electron microscopies, Electron Beam – Specimen Interaction, Secondary and Backscattered electrons, Interaction cross-section and volume, Scanning electron microscope (SEM), operational systems of SEM instrumentation and imaging modes, energy dispersive X-ray spectroscopy, transmission electron microscope, selected area electron diffraction, pattern writing using optical and electron beams.

Spectroscopies: Characterization of fluorescence emission, Jablonski diagram, fluorescence quantum yield and life time, instrumentation for fluorescence spectroscopy, absorption and photoluminescence spectroscopy, Tauk plot, energy band gap determination, Raman spectroscopy, Fourier transform infrared spectroscopy, X-ray photoemission spectroscopy, X-ray absorption spectroscopy, Nuclear magnetic resonance (NMR) spectroscopy.

Unit III (14 hours)

Surface Morphology and Topography, scanning probe microscopy, scanning tunneling microscope (STM), atomic force microscope (AFM), concept and modes of operation of STM and AFM, conducting AFM.

Rutherford backscattering spectrometry, scattering geometry and kinematic factor, scattering cross-section, energy loss and stopping cross section, energy straggling, surface impurity on an elemental bulk target, Thermogravimetric analysis and differential thermal analysis: principle and instrumentation, differential scanning calorimetry.

Unit IV (5 hours)

Physical Properties: Electrical measurements: Resistivity, temperature dependence of resistivity in materials, resistance in bulk and low-dimensional systems, Current voltage characteristics, estimation of resistivity using four probe Van-der Pauw methods.

Dielectric and magnetic measurements: Frequency dependence on capacitance-voltage characteristics, estimation of dielectric constant. diamagnetics, paramagnetics, feromagnetics, B-H loop, operation and analysis of vibrating-sample magnetometry, ferroelectrics, polarization-electric field loop.

Course Learning Outcomes:

The students should able to experience the advanced characterization techniques pursued in the experimental condensed matter physics for studying the physical properties of the materials in the semiconductor technologies and nanotechnology.

Suggested readings:

1) X–Ray Crystallography by M. J. Buerger: Wiley–Blackwell; 99th ed. edition (1 January 1966)
2) Elements of X-ray Diffraction by B. D. Cullity: Addison-Wesley Publishing Company Inc. (1978)
3) Analytical Electron Microscopy for Materials Science by D. Shindo and T. Oikawa, Springer Verlag, Japan; 2002nd edition
4) Handbook of Spectroscopy edited by Günter Gauglitz, Tuan Vo-Dinh: WILEY-VCH Verla GmbH & Co, 2003
5) Scanning Probe Microscopy: Atomic Force Microscopy and Scanning Tunneling Microscopy by Bert Voigtländer, Springer-Verlag Berlin Heidelberg, 2015

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-DSE4214

Course Name: Experimental Technique in Nuclear Science

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Experimental Technique in Nuclear Science DSE	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objective

To provide a comprehensive understanding of the principles of radioactivity and nuclear decay processes required for experiments performed at the laboratory. To familiarize students with the interaction of nuclear radiation with matter and the mechanisms involved. To introduce various radiation detectors, counting techniques, and statistical methods used in nuclear experiments. To equip students with foundational knowledge of signal processing and applications of nuclear radiation in diverse fields.

Content

Unit I (10 hours)

Radioactivity: Introduction to Radioactivity, Decay Law, Units and Production of radioactivity, Radioactive sources, Growth of Daughter activities, , Branching Ratios, Half-life and mean life, Nuclear Decay processes, Decay Equation, Decay Schemes, Alpha Decay: alpha decay energies, qualitative theory of alpha decay and alpha-ray spectra, Beta Decay: Beta spectrum, Gamma Decay: Energetics and spectrum, Semiempirical Mass Formula, Q-value of Decay and reactions.

Unit II (10 hours)

Interaction of Radiation with Matter: Interaction of light charged particles with matter, Ionization, Bragg Curve and Bragg Peak, Range and Energy Relation, Radiation length and straggling, Interaction of Gamma Radiation with Matter: Attenuation of Gamma rays, Compton Effect, Photoelectric Effect and Pair Production, Attenuation and absorption Coefficients.

Unit III (12 hours)

Radiation Detectors and Counting Statistics: Classification, Gas-filled Detectors: Ionisation, Proportional and Geiger-Muller Counters; Concept of Multiplication, Quenching, and Dead Time. Brief introduction of scintillators and semiconductor detectors,

Types of uncertainties in a measurement, Probability and Cumulative distribution function, variance and standard deviation; Binomial, Poisson and Gaussian distribution, Error Propagation

Unit IV (13 hours)

Basics of Signal Processing: Basic electronic circuits for signal processing (GM and Scintillator detectors), Logic standard, Pulse shaping and digital signal processing for energy, time and position measurement, Digital Oscilloscope.

Application of Nuclear Radiation in Medicine, Industry, Research, Security, Agriculture and Space.

Learning outcome

After successful completion of the course, students will be able to: Understand and explain the physical principles governing radioactive decay and nuclear interactions. Analyze the behavior of nuclear radiation as it passes through matter and interpret relevant parameters such as range, attenuation, and energy loss. Select and apply appropriate radiation detection techniques and interpret experimental data using statistical analysis. Demonstrate an understanding of signal processing techniques and recognize real-world applications of nuclear science in medicine, industry, and other sectors.

Suggested Readings:

1. Radiation Detection and Measurement by G. F. Knoll (3rd Ed. John Wiley & Sons, Inc.,2000)
2. Physics & Engineering of Radiation Detection by S. N. Ahmed (Academic Press 2007)
3. Techniques for Nuclear and Particle Physics Experiments by W.R. Leo (Springer-Verlag 1987)
4. Nuclear Physics, Principles and Applications by J.S. Lilly (John Wiley & Sons, Inc., 2002).
5. Radiation Detection: Concept, Method and Devices by Douglas S. McGregor and J. Kenneth Shultis, (Taylor and Francis 2020)

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-DSE4115

Course Name: Technique in Theoretical Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Technique in Theoretical Physics DSE	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

The course will introduce to the students' basic concepts of finite and infinite groups. Examples from various fields will be considered. Techniques for solving integral equations will be learnt. Introduction to Green functions and its construction will be studied.

Contents:

Unit I (10 hours)

Introduction of finite discrete Group: subgroups, classes, cosets, factor groups, normal subgroups, direct product of groups; Examples: cyclic, symmetric, matrix groups, regular n-gon. Mappings: homomorphism, isomorphism, automorphism. Representations: reducible and irreducible representation, unitary representations, Schur's lemma and orthogonality theorems, characters of representation, direct product of representations.

Unit II (15 hours)

Continuous Group: Review of the continuous groups: Lie groups, rotation and unitary groups. Representation of SO(2), SO(3), SU(2), SU(3), Tensors. Applications: point groups, translation and space groups, representation of point groups; introduction to symmetry group of the Hamiltonian.

Unit III (10 hours)

Integral Equations: Conversion of ordinary differential equations into integral equations, Fredholm and Volterra integral equations, separable kernels, Fredholm theory, eigen values and eigen functions.

Unit IV (10 hours)

Green function: Boundary Value Problems: boundary conditions: Dirichlet and Neumann; self-adjoint operators, Sturm-Liouville theory, Green's function, eigenfunction expansion.

Course Learning Outcomes

The understanding of the classification of finite groups will be achieved. Upon completion of this course, students should be able to use these concepts in various fields, particularity in crystallography. Students will be able to learn the different analytical techniques for solving integral equations and construct Green's functions for many important boundary value problems.

Suggested Readings:

1. Elements of Group Theory for Physicists, A.W. Joshi (John Wiley, 1997).
2. Groups and Symmetry,M. A. Armstrong(Springer, 1988).
3. Advanced Method of Mathematical Physics, R. S. Kaushal & D. Parashar (Narosa, 2008).
4. Group Theory and Its Applications to Physical Problems, M. Hamermesh (Dover, 1989).
5. Chemical Applications of Group Theory, F. Albert Cotton (John Wiley, 1988).
6. Mathematical Methods for Physicists,G. Arfken, H. Weber, & F. Harris (Elsevier, 2012).
7. Linear Integral Equations, W. V. Lovitt (Dover, 2005).
8. Introduction to Integral Equations with Applications, A. J. Jerri (Wiley-Interscience, 1999).

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-DSE4216

Course Name: Theoretical Techniques in the Quantum World

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Theoretical Techniques in the Quantum World DSE	4	3	1	0	QM I and II.

Duration: 60 hours (45L+15T)

Course Objectives

To introduce students to a simple and elegant class of quantum mechanical systems with supersymmetry, and to explore what it can teach us about the geometry of low-dimensional surfaces.

Contents:

Unit I: Supersymmetry in Quantum Mechanics (11 hours)
Supersymmetry in zero dimensions. Supersymmetry algebra in quantum mechanics and its implications for the spectrum of quantum mechanical systems. Spontaneous breaking of supersymmetry. The Witten index. Supersymmetric actions.

Unit II: Path Integrals (11 hours)
Path integrals in quantum mechanics. The partition function and the Witten index as a path integral. Instantons, tunneling, and the dilute gas approximation. Zero modes and determinants.

Unit III: Morse Theory (11 hours)
Singular homology and homology groups. Differential forms and de Rham cohomology. Betti numbers. de Rham's theorem. Hodge operators. Harmonic forms.

Unit IV: Supersymmetry and Morse Theory (12 hours)
Sigma models. Supersymmetry and Morse theory. Connection to the topology of low-dimensional surfaces.

Course Learning Outcomes
Students will learn about supersymmetry in its simplest setting: ordinary quantum mechanics. They will also learn about its relation to Morse theory and the topology of low-dimensional surfaces, a beautiful example of the synergy between physics and mathematics. Students keen on specialising in theoretical high-energy physics and string theory will find this course particularly useful.

Suggested Readings:

1) Geometry, Topology and Physics, Mikio Nakahara, Taylor & Francis (CRC Press), 2nd Edition, 2003.
2) Mirror Symmetry, Kentaro Hori et al., American Mathematical Society, Clay Mathematics Monographs, Volume 1, 2003.

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-SBC4271

Course Name: Workshop skills

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Workshop skills SBC	2	0	0	2	

Duration: 60 hours

Course objective:

The aim is to teach them how to handle machines that can be useful for precise cutting in lab accessories, useful for experiments.

Content:

Hands-on experience:

Unit-I:

- Lathe machine (Plane turning, step turning, taper turning)
- Drill machine

Unit-II:

- Plate cutting
- Hand tools (hacksaw, drilling, tapping, filing)

Course Learning outcome:

The student will be confident and skilled for handling lab useables and small repairs.

(Not more than seven students at a time due to space constraint and safety.)

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-SBC4272

Course Name: Computational Physics

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Computational Physics SBC	2	0	0	2	

Duration: 60 hours

Course Objective

This is an introductory course where students will learn the various numerical methods to solve physics problems through a programming language(Python).

Prerequisite: Basic knowledge of Python

Content:

Unit-I:

- Numerical Integration: Simpson, Trapezoidal, Gauss Quadrature
- Random number, Monte Carlo Integration

Unit-II:

- Differential equations: Euler method, Runge-Kutta
- Application to Physics problems: Schrodinger Equation using iterative method

Course Learning Outcomes

A student having taken the course would be expected to be proficient in numerical methods using a programming language (Python). In addition, it is also expected that the student would be able to use the same to solve problems involving Integration and Differential equations.

Suggested reading:

1. Lab manual for Computational Physics, Department of Physics and Astrophysics, University of Delhi 2025.
2. https://www.python.org/doc/
3. Monte Carlo Simulation in Statistical Physics: An Introduction, Binder, Kurt, Heermann, Dieter (5th Ed., Springer, 2010)
4. Numerical Analysis, Richard L. Burden, J. Douglas Faires, Annette M. Burden (10th Ed., Cengage Learning, 2016)

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-SBC4273

Course Name: Amateur Astronomy

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Amateur Astronomy SBC	2	0	0	2	

Duration: 60 hours.

Course objective:
The students taking this course can make cost effective telescopes to enjoy their astronomy skills.

Content:
Unit-I: Designing of an optical telescope.

Unit-II:
- Projection of sun and counting the sun spots
- Identification of celestial objects.

Course Learning Outcome:
The students will participate actively in designing telescopes and conducting measurements for celestial objects

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-SBC4274

Course Name: Magnet design and simulation

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Magnet design and simulation SBC	2	1	0	1	

Duration: 45 hours (15L+30P)

Course Objectives:

To impart foundational knowledge on the principles and engineering design of magnetic systems used in accelerators, beamlines, and scientific instrumentation. To classify and analyze the operation of various types of magnets (dipole, quadrupole, sextupole, etc.). To equip students with simulation and analytical skills necessary for magnet design. To understand the thermal, structural, and magnetic field considerations during the design of static and dynamic magnetic systems.

Course Contents

Unit-I:

- **Introduction to Magnet Design:** Magnetic field and flux density basics**,** B-H curves, permeability, hysteresis**,** Classification: dipole, quadrupole, sextupole, solenoid.
- **Magnetic Materials and Core Selection**: Soft and hard magnetic materials, Laminated cores, yoke design, material properties (μr, saturation), Magnetization curves and losses.
- **Dipole Magnet Design:** Principle of uniform magnetic field generation, Pole face shaping, air gap design,Analytical expression for magnetic field and flux in C-type and H-type cores.
- **Quadrupole Magnet Design:** Field gradient, pole tip profile, Rotational symmetry and mechanical tolerances, Equations of motion for charged particles in quadrupole fields. **Sextupole and Higher Order Multipoles**: Field expansion, nonlinear field components, Correction of chromatic aberrations using sextupoles, Applications in beam focusing and correction.
- **Magnetic Circuit and Reluctance**: Ampere's Law and magnetic equivalent circuits, Calculation of magneto-motive force (MMF), reluctance, flux, Application to closed and open magnetic paths.
- **Coil and Conductor Design**: Current density, number of turns, cross-section, Insulation, cooling channels, bus bars, Power supplies and magnet energization.

Unit-II:

- **Thermal and Structural Considerations**: Joule heating, eddy currents, thermal management, Mechanical stresses, Lorentz forces, Cooling methods: water, oil, cryogenic.
- **Fringe Fields and Field Mapping:** Edge field effects, shielding, Field mapping using Hall probes and rotating coils, Magnetic center alignment.

- **Field Quality and Tolerances**: Harmonic analysis, Measurement techniques, Effect of geometric errors.
- **Pulsed Magnets and Eddy Currents**, Pulsed dipoles and kickers, Skin effect, rise time, and decay time, Eddy current suppression and laminated cores.
- **Superconducting Magnet Design (Introductory):** Benefits of superconductors in magnet design**,** Cryostat and quench protection basics**,** Applications in large accelerators.
- **Overview of Indian and Global Magnet Projects:** Magnet design at RRCAT, VECC, IUAC, CERN, BNL, and KEK**,** Industry-academia collaborations**,** Indigenous magnet manufacturing and QA practices.

Skill Development Lab & Simulation

- **Tools & Platforms: FEMM** (Finite Element Method Magnetics) **–** Free 2D simulation,
- **Opera/TOSCA –** Commercial (if available),
- **COMSOL Multiphysics –** 2D/3D magnetostatics module, Python/Matlab for analytical calculations.

Lab Activities:

	Lab Exercise	**Tool**	**Description**
1	Introduction to FEMM	FEMM	Create geometry, assign boundary conditions
2	2D Dipole Simulation	FEMM	Compute field lines and flux density in dipole geometry
3	Analytical Calculation of Dipole Field	Python/Manual	Compare with FEMM result
4	Quadrupole Field Simulation	FEMM	Compute field gradient, plot field contours
5	Pole Tip Shaping	FEMM	Investigate effects of different profiles
6	Magnetic Circuit Calculation	Python/Excel	Calculate MMF and reluctance
7	Sextupole Design Simulation	FEMM	Design and visualize higher-order field
8	Eddy Current Loss Estimation	FEMM/ COMSOL	Pulsed magnet simulation
9	3D Magnet Design Overview	COMSOL	Field distribution visualization (if available)
10	Comparison of Magnetic Materials	FEMM	Simulate using different B-H curves
11	Cooling Analysis	Manual/Excel	Power loss and cooling requirement estimation
12	Simulation of Field Mapping	FEMM	Simulate rotating coil/Hall probe path

Course Learning Outcomes:

Upon successful completion of this course, students will be able to: Describe the design principles and physical function of static magnets used in beam control and steering. Compute magnetic field distributions, gradients, and forces analytically for simple geometries. Use electromagnetic simulation software (e.g., FEMM, Opera, COMSOL) for modeling 2D/3D magnet systems. Analyze key design constraints including saturation, eddy current losses, and cooling requirements.

Suggested Reading:

1. Design of Permanent Magnet Multipole Devices, Klaus Halbach & Richard F. Holsinger, (Volume:10553, Technical Report, Lawrence Berkeley Laboratory, LBL, 1976).
2. Field Computation for Accelerator Magnets, Stefan Russenschuck (3rd Edition, Wiley-VCH Verlag GmbH & Co. KGaA, 2018).
3. Iron Dominated Electromagnets, Jack T. Tanabe (2nd Edition, World Scientific Publishing, 2005).
4. Magnet Design: Theory and Practice, W. T. Norris, (on behalf of the IEE) (1st Edition, Peter Peregrinus Ltd., 1983).
5. FEMM Documentation and Online Tutorials, David Meeker (Distributed via FEMM Software Website, Version 4.2 or latest, 2015).

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-SBC4275

Course Name: Data Interpretation and Simulation

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Data Interpretation and Simulation SBC	2	1	0	1	

Duration: 45 hours (15L+30P)

Course Objectives

To develop the ability to interpret, analyze, and present scientific data using modern computational tools. To provide hands-on experience with ROOT (CERN), Origin, and Python for data analysis and visualization. To introduce basic simulation techniques for modeling physical phenomena and experimental processes. To enhance skills required for scientific reporting and reproducible research in experimental/theoretical physics.

Course Contents

Unit I: Data Handling and analysis with Python (8 hours)

- Types of data: experimental, simulated, observational
- Basic statistics: mean, median, standard deviation, error bars
- Introduction to GNUPlot: plotting, curve fitting, peak analysis
- Data import/export, managing datasets, graphical presentation
- Basics of Python: variables, loops, functions
- NumPy, Pandas, and Matplotlib for data handling and visualization
- Linear regression, curve fitting using SciPy
- Plotting histograms, scatter plots, error bars, etc.

Unit II: Introduction to ROOT (CERN) and Simulation Techniques (7 hours)

- Overview of ROOT and its architecture
- Working with histograms, trees, and graphs
- Data fitting, statistical tools, multi-plotting
- ROOT scripting (C++ and PyROOT) basics
- Concept of numerical simulation
- Monte Carlo method basics

- Simulation of physical processes (radioactive decay, random walk, detector response)
- Visualization of simulation output

Laboratory Work (30 hours)

Hands-on assignments based on:

- GNUPlot: Curve fitting, interpolation, error analysis
- Python: Reading and visualizing experimental data, statistical analysis
- ROOT: Creating histograms, performing fits, simulating data
- Mini project involving data analysis and basic simulation of a physical phenomenon (e.g., particle interaction, decay process, or signal response)

Course Learning Outcomes

Upon successful completion of this course, students will be able to: Interpret and statistically analyze experimental and simulated data using scientific software. Visualize and fit data using tools such as Python, GNUPlot, and ROOT. Simulate basic physical systems and analyze outcomes in comparison to real datasets. Generate scientific plots and reports suitable for publications or thesis work.

Suggested Reading

1. Data Reduction and Error Analysis for the Physical Sciences, Bevington & Robinson
2. Think Stats: Exploratory Data Analysis in Python, Allen B. Downey
3. ROOT User's Guide – CERN Documentation (https://root.cern/manual/)
4. Mark Newman's Computational Physics
5. Python Documentation – https://docs.python.org

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-SBC4276

Course Name: Electronic circuit and simulation

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Electronic circuit and simulation SBC	2	0	0	2	

Duration: 60 hours.

Course objective :

The students will get the opportunity to build and test different electronic circuits using softwares

Content:

Unit-I: Labview training.

Unit-II: Pspice training.

Course Learning Outcome:

The student will be able to engineer different electronic circuits for real world utilization

MASTER of SCIENCE in PHYSICS

Semester II

Course Code: PH-SBC4277

Course Name: Strategies for Scientific Dialogue in Research

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Strategies for Scientific Dialogue in Research SBC	2	1	0	1	

Duration: 45 hours (15L+30P)

Course Objectives:

The course is designed to develop and strengthen students' ability to communicate scientific ideas clearly and effectively, both in written and oral formats. It aims to expose students to cutting-edge research through seminars delivered by faculty members and invited experts. Emphasis is placed on cultivating skills in scientific literature review, critical analysis, and academic discourse. The course also prepares students for academic presentations, thesis defenses, and professional scientific interactions. Recognizing that many students produce excellent research but struggle to present it effectively, this course seeks to bridge that crucial gap.

Course Learning Outcomes:

Upon successful completion of the course, students will be able to: Comprehend and effectively communicate recent research developments in physics and allied disciplines. Summarize and synthesize scientific literature with clarity, coherence, and critical insight. Prepare and deliver well-structured, confident, and audience-appropriate scientific presentations. Engage thoughtfully in scholarly discussions and respond competently to academic queries.
This course will be particularly beneficial for students planning to undertake project work or a dissertation in the third and fourth semesters.

Course Structure and Activities:

UNIT -I (15 hours)

Lecture Attendance & Research Exposure:

- ➢ Students must attend a minimum of 10 research lectures organized by the department. These may include:
  1. Presentations by department faculty on their current research.
  2. Lectures by invited national or international experts.
- ➢ Students will submit comprehensive summaries (approx. 400–500 words) of at least five selected lectures, highlighting key concepts, methods, and findings.

UNIT -II (30 hours)

Seminar Preparation and Delivery:

- ➢ Students will be assigned a research topic or paper, drawn from current research themes or courses offered in the M.Sc. syllabus.
- ➢ They will receive study materials, including relevant papers, reviews, or resources from the faculty.
- ➢ Each student must prepare a written synopsis (~800–1000 words) on the assigned topic.
- ➢ Students will then present a seminar (15–20 minutes) based on their understanding, followed by a Q&A session.

The course is structured in the spirit of a Dissertation under the DSE category, but with lower credit weightage and, accordingly, reduced academic rigor. As such, the number of hours assigned is indicative rather than prescriptive, intended to reflect the approximate level of effort expected.

Assessment and Evaluation:

Component

i) Participation in Departmental Lectures
ii) Written Summaries of Attended Lectures
iii) Written Review of Assigned Research Topic
iv) Seminar Presentation (Content, Clarity, Delivery)

The Evaluation will be conducted by:

i) A three-member departmental committee for the overall course.
ii) A two-member subcommittee for seminar presentation evaluation.

Notes for Implementation:

- ➢ Attendance at department seminars will be tracked.
- ➢ Students may optionally include key questions or insights from each attended lecture.
- ➢ Emphasis will be placed on communication skills, depth of understanding, organization of content, and response to questions.
- ➢ This course encourages peer learning and academic engagement beyond the classroom.

General Electives (GEC) courses

General Electives (GE) courses to be offered to other departments					
PH-GEC1 Radiation Safety	67	3	0	1	4
PH-GEC2 Introductory Astronomy	70	3	0	1	4
PH-GEC3 Complex System & Networks	72	3	0	1	4
PH-GEC4: Physics for Biological Systems	74	3	0	1	4
PH-GE5: Physics Education	76	3	0	1	4

SELECTION OF GENERAL ELECTIVE COURSES: Guidelines

SEMESTERS I to IV: Students may opt for four General Elective courses in lieu of Department-Specific Elective (DSE) courses—one General Elective course in each of the four semesters—adding up to a total of 16 credits.

- ❖ Certain General Elective Courses may have prerequisites. Students should keep this in mind while opting for General Elective courses.
- ❖ Allotment of General Elective Courses will be based on the choices indicated by the student, performance of the student in earlier semester(s) and availability of seats.

Open electives (GE papers) to be offered to other departments

MASTER of SCIENCE in PHYSICS

Semester I /II/III/IV

Course Code: PH-GEC0001

Course Name: Radiation Safety

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Radiation Safety GEC	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

This course is aimed to introduce the student to practical aspects of nuclear radiation with an understanding of basic quantities and doses, the role of fundamental processes involved in the interaction of X- rays, gamma-rays, charged particles and neutrons with matter, the principles underlying the operation of nuclear detection/dosimetry instruments, areas of applications, awareness of the need and methods for safety protocols for radioactive material and environmental safety.

Contents:

Unit I (8 hours)

Basics of Radiation: Origin of radiation, binding energy and Q-value, stable and unstable isotopes, radioactive decay (alpha, beta, neutron and electromagnetic transitions), mean life and half life, nuclear reactions, concept of cross sections and attenuation co-efficients, Neutron flus, kinematics of nuclear reactions. Slowing down and moderation. Basic idea of different units of activity, radiation quantities: exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, quality factor, radiation and tissue weighting factors, KERMA, Annual Limit of Intake (ALI) and Derived Air Concentration (DAC).

Unit II (15 hours)

Devices for radiation measurement and survey:Radiation interaction with matter.

Introduction to types of radiation detectors: semiconductor, scintillator and gas detectors (Geiger-Muller counters, ionisation chamber and proportional counters) Principles of radiation counting statistics, dead time and calibration standards.

Types of Radiation Dosimeters: thermoluminescence, radiographic films, calorimetry, semiconductor diodes; Relation between detection and dosimetry; exposure measurements with free air chamber.Interaction ofionising and non-ionising radiation at the cellular level.

Application of Nuclear techniques: Medical science (e.g., MRI, PET, Projection Imaging Gamma Camera, radiation therapy), Art & Archaeology, Art, Crime detection, Oil &Mining, Water assessment, Industrial Uses: Tracing, Gauging, Material Modification, Sterilization, Food preservation.

Unit III (12 hours)

Radiation Protection Standards: Classification of radioactive sources, Radiation dose to individuals from natural radioactivity in the environment and man-made sources, Basic concept of radiation protection standards: historical background, International Commission of Radiological Protection and its recommendations, the system of radiological protection, justification of practice, optimization of protection and individual limits, radiation and tissue weighting factors, committed equivalent dose, committed effective dose, concept of collective dose, potential exposures, dose and dose constraints, system of protection for invention-categories of exposures-Occupational, Public and Medical exposures, Permissible levels for neutron flux, factors governing internal exposure-Radionuclide concentration in air and water –ALI, DAC and contamination levels, effects of inhaled radionuclides on biological systems, impact on humans and society.

Unit IV (10 hours)

Regulations, Monitoring, & Radioactive Waste Management: Evaluation of external radiation hazard-effect of distance, tome and shielding, shielding calculation, personnel and area monitoring-internal radiation hazards, radio toxicity of different radio nuclides and the classification of laboratories, control of contamination-bioassay and air monitoring, chemical protection, Radiation accidents and disaster monitoring, Sources & classification of Radioactive waste, permissible limits for disposal of waste, general method of disposal, storage management of radioactive waste in facilities. Responsibilities of operator, regulatory bodies, and government.

Course Learning Outcomes

A knowledge of the principle of operation of various radiation detectors, understanding of radiation dose calculation and permissible doses for different levels of users, and radiation effects, an understanding of instrumentation in practical situations, awareness about the management of radioactive material, and adherence to safety protocols,

Suggested Readings

1. Nuclear and Particle Physics, W. E. Burcham and M. Jobes (Pearson Education, 1995)
2. Radiation detection and measurement, G. F. Knoll (4^{th} Ed., Wiley, 2010)
3. Thermoluninescense Dosimetry, Mcknlay, A. F., Bristol, Adam Hilger (Medical Physics Hand book 5)
4. Fundamental Physics of Radiology, W. J. Meredith and J. B. Massey (John Wright and Sons, 1989)
5. An Introduction to Radiation Protection, A. Martin and S. A. Harbisor (John Willey & Sons, 1981)

6. Medical Radiation Physics, W. R. Hendee (Medical Publishers Inc., 1981)
7. Nuclear Physics : Principles and applications, John Lilley (Wiley, 2001)
8. Physics and Engineering of Radiation Detection, Syed Naeem Ahmed (2nd Ed., Elsevier, 2014)
9. Techniques for Nuclear and Particle Physics Experiments, W.R. Leo (2nd Ed., Springer, 2013)
10. IAEA Publications : (a) General safety requirements Part 1, No. GSR Part 1 (2010), Part 3 No. GSR Part 3 (Interium) (2010); (b)Safety Standards Series No. RS-G-1.5 (2002), Rs-G-1.9 (2005), Safety Series No. 120 (1996); (c) Safety Guide GS-G-2.1 (2007).
11. AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities.
12. AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources.

MASTER of SCIENCE in PHYSICS

Semester I/II/III/IV

Course Code: PH-GEC0002

Course Name: Introductory Astronomy

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Introductory Astronomy GEC	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

Since this course is an open elective, with students from diverse background opting for it, the primary objective is to impart a basic knowledge about the oldest branch of physical science through a conceptual mode, relying less on mathematics and more on physical understanding. Since exciting new developments have been taking place in the astronomy of 20-th and 21-st centuries, with India playing crucial roles, the idea is to enable students to have a flavour of both historical and modern aspects so that they acquire a perspective of their place in the universe..

Contents:

Unit I (7 hours)

Antiquity of astronomy: Planets and stars in Egyptian and Babylonian civilizations; Possible reference to stars and planets in Indus Valley Civilization; stars and constellations in Rig Veda as well as in other vedic literature; reference to Halley's comet in a Babylonian clay tablet; Far Eastern astronomy - comets and Crab supernova; reference to cosmic objects in mythologies, classic literature and science fictions.
Early astronomical measurements: Measurement of Earth's radius by Eratosthenes; Lunar and solar motion studies by Hipparchus - equinoxes and solstices, lunar and solar eclipses; Aryabhatta I and his seminal contributions to astronomy - relative motion, spinning Earth, eclipses, etc.; Varahamihira, Brahmagupta and other siddhantic astronomers of India; symbiotic relation between mathematics and astronomy; evidence of the precession of equinox from vedic literature; Jai Singh and his Jantar Mantar.

Unit II (12 hours)

Solar system: geocentric model - Ptolemy, Tycho Brahe and Samanta Chandrasekhar; retrograde motion of Mars and theory of epicycles; Copernicus and the heliocentric model; Kepler's laws of planetary motions - a formulation based on a set of mathematical laws for the first time in physical sciences; Galileo's pioneering work - length and time measurements, telescope, lunar craters, moons of Jupiter, rings of Saturn, corroboration of Copernican model, Pisa tower and equivalence principle.
Laws of gravitation- motion of the Moon around the Earth, falling bodies, Newton's genius; Halley's comet and laws of gravity; importance of gravity as a force in astronomy; Physics of the Sun; Thermonuclear reactions; discovery of Neptune and Pluto; asteroid belt,

meteors and comets; Tidal forces and the oceanic tides; precession of equinox and change of seasons; dating Rig veda using the precession of equinox; Distances - parallax method; standard candles - Cepheid variables and Henrietta Leavitt, Type Ia Supernovae; Spectroscopy - atomic spectra, emission and absorption lines, their widths and Doppler shifts.

Unit III (18 hours)

Stellar population and Hertzsprung-Russell diagram; Meghnad Saha, ionized element, Saha equation and birth of astrophysics; Wilson-Bappu effect and stellar distances; Stellar structure and evolution- evolution of low mass stars and high mass stars; white dwarfs - Fowler, Chandrasekhar and Eddington; Chandrasekhar's mass limit; Baade and Zwicky - supernova and neutron stars; supernova explosion; pulsars.

Milky Way and other galaxies: Shapley-Curtis debate; measurement of Doppler shift in emission lines by Humason, Slipher and Hubble; Cepheid variable and distances of galaxies; Classification of galaxies - spirals, ellipticals, irregulars, dwarfs, lenticulars, etc.; Hubble's law and birth of cosmology as a scientific discipline; big bang and steady state models; Hoyle-Narlikar cosmology;radio source counts, evolution of radio-sources and setback to steady-state theory; angular resolution, radio interferometry and large baselines; detection of apparent superluminal motion; radio telescopes in India - Govind Swarup and his collaborators

Unit IV (8 hours)

The Universe: Penzias, Wilson and the cosmic microwave background; corroboration of thermal history in big bang cosmology as predicted by Gamow and his collaborators; Big bang model, singularity and Raychaudhuri equation; clusters of galaxies; Zwicky and the dark matter; the observed large scale structure; Vera Rubin and the evidence of dark matter from galactic rotation curves; Type Ia supernovae and accelerating universe; the puzzle of dark energy; new astronomy - X-ray and gamma ray astronomy, gravitational waves, neutrino astronomy, thirty metre telescope and the square kilometre array; discovery of exoplanets.

Course Learning Outcomes

A historical perspective of the development of Astronomy. Conceptual understanding of basic principles involved. A flavour of current developments in this field and India's role in them. Appreciation of laws of nature that are discovered on Earth but which explain successfully distant cosmic objects and the universe as a whole

Suggested Readings

1. The Physical Universe, Frank Shu (University Science Books, 1982)
2. Cosmology: The Science of the Universe, Edward Harrison (Cambridge University Press, 2000)
3. From Black Clouds to Black Holes, J. V. Narlikar (World Scientific, 1985)
4. Archeoastronomy- Introduction to the Science of Stars and Stones, Giulio Magli (Springer, 2016)

MASTER of SCIENCE in PHYSICS

Semester I

Course Code: PH-GEC0003

Course Name: Complex System & Networks

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Complex System & Networks GEC	4	3	1	0	

Duration: 60 hours (45L+15T)

Objectives:

This course deals with the interdisciplinary subject of complex systems, that include, among others, living organisms, ecosystems and human societies. The course emphasizes a unifying theme – complex networks – that cuts across all these systems. It develops the mathematical tools of graph theory and dynamical systems to provide insight into the structure, dynamics and evolution of a variety of complex systems in the physical sciences, life sciences, social sciences and engineering.

Contents:

Unit I (7 hours)

Overview: Examples of complex systems: organisms, brains, ecosystems, societies, the internet. Components of these systems: molecules, cells, species, agents, computers. Collective phenomena exhibited by these systems. Contrast with other collective phenomena in physics such as phase transitions. Adaptive nature of these systems.

Unit II (10 hours)

Graph theory and the network structure of complex systems: Complex networks of interaction as a unifying theme underlying complex systems. Undirected, directed and bipartite graphs, hypergraphs. Adjacency matrix of a graph. Graph theoretic measures of network structure. Random graph ensembles, small-world, scale-free, hierarchical and autocatalytic graphs. Network motifs. Nature of graphs that arise in various complex systems

Unit III (14 hours)

Dynamics of complex systems: Dynamics on a fixed network. Examples of continuous and discrete dynamical systems to be taken from various complex systems such as chemical networks, metabolic networks, ecological food webs, genetic regulatory circuits, neural networks, social and economic networks, epidemiological networks. Fixed point and limit cycle attractors of these systems. The influence of network structure on dynamics.

Unit IV (14 hours)

Evolution of complex systems: How networks change over time. Preferential attachment model of scale free networks. The origin of life puzzle. Model of autocatalytic network evolution and self-organization of a complex network. Community assembly models in ecology. Evolution of biological and social networks. Crashes and recoveries in complex systems. Robustness and fragility of complex systems.

Course Learning Outcomes

Being able to appreciate that complex networks of interacting components underlie many complex systems studied under different disciplines. Learning the similarities and differences between complex systems from the perspective of network structure.Learning certain mathematical methods of graph theory and dynamical systems.Being able to apply these methods to characterize the structure of various complex systems and to model certain phenomena exhibited by them.

Suggested Readings

1. Networks: An Introduction, M. E. J. Newman (Oxford University Press, 2010).
2. Origins of Order, Stuart Kauffman (Oxford University Press, 1993).
3. Handbook of Graphs and Networks: From the Genome to the Internet, S. Bornholdt and H.-G.Schuster (Wiley-VCH, 2003).
4. Dynamics of Complex Systems, Yaneer Bar Yam (Perseus Books, 1997)

Prerequisites for the course: Students should have taken Mathematics as a subject in high school (Classes XI and XII).

MASTER of SCIENCE in PHYSICS

Semester I/II/III/IV

Course Code: PH-GEC0004

Course Name: Physics of Biological Systems

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics of Biological Systems GEC	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

This open elective course will introduce students to selected biological phenomena from the point of view of physics, emphasizing quantitative regularities. It will enable students from non-biology backgrounds to gain an overview of living systems, and those from biology backgrounds to perform mathematical modelling of certain biological processes.

Pre-requisites: Any branch of Science in Bachelors.

Contents:

Unit I (10 hours)

Length and time scales in biology: Types, sizes and roles of biomolecules - metabolites, proteins, RNA, and DNA. Ranges of cell sizes and interdivision time scales,. Ranges of organism sizes and lifetimes, Scaling laws in biology, Complexity of living systems, Timeline of life on Earth, Time scales in biological evolution. Experimental techniques.

Unit II (14 hours)

Cellular dynamics: Dynamical systems, coupled ordinary differential equations, Phenomena and models of intracellular chemical dynamics. Reaction-diffusion systems, Ecological interactions: Predator-prey model.

The brain: Dynamics of a single neuron, Neural networks, Learning, Memories as attractors of neural network dynamics.

Unit III (9 hours)

Information in living systems: Probability, entropy and information, Applications of Information theory in genetics. Brownian motion of colloids.

Unit IV (12 hours)

Random walk in d=1,2,3 and Self-avoidance, classification and conformations of polymers and related Scaling, structures of DNA, simulation methods and related experiments.

Course Learning Outcomes

Gain knowledge of structures and processes in living systems at multiple length and time scales, including at the level of molecules, cells, multi-cellular organisms and ecosystems. Appreciate that life is a consequence of physical processes at the molecular level. Learn certain mathematical methods of dynamical systems, probability and information theory. Also, to learn a few techniques for numerical simulations of proteins or biopolymers. Be able to apply these methods to model certain biological phenomena

Suggested Readings

1. Physics in Molecular Biology, Kim Sneppen and Giovanni Zocchi (CUP 2005).
2. Biological Physics: Energy, Information, Life, Philip Nelson (W. H. Freeman &Co, NY, 2004).
3. Biophysics: Searching for Principles, William Bialek (Princeton University Press, 2012).
4. Physical Biology of the Cell (2nd Edition), Rob Phillips et al (Garland Science, Taylor & Francis Group, 2013).
5. An Introduction to Systems Biology, Uri Alon (Chapman and Hall/CRC, 2013).
6. Mathematical Biology: I. An Introduction, J. D. Murray (3rd Ed., Springer, 2004).

MASTER of SCIENCE in PHYSICS

Semester I/II/III/IV

Course Code: PH-GEC0005

Course Name: Physics Education

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics Education GEC	4	3	1	0	

Duration: 60 hours (45L+15T)

Course Objectives

This Discipline Specific Elective Course will develop pedagogic knowledge for teachinglearning of physics informed by global best praxis. It will delineate procedural and content knowledge for meaningful laboratory work; and design of appropriate technology enhanced active learning environments.

Contents:

Unit I (5 hours)

Foundations of Teaching-Learning of Physics: Goals of physics teaching. Beliefs and Epistemological Expectations and how they impact teaching-learning of physics. Theoretical models of student learning. Structure of knowledge. Difference between novice learners and experts. Theories of cognition. Constructivist and social theories of learning. Guided Enquiry and Active Learning. Engendering cognitive change.

Unit II (12 hours)

Effective Teaching-Learning Strategies: Models of Classroom. Traditional instructor centred environment vs Active engagement student centred environment. Physics Education Research (PER): What works and what does not work. Designing Lecture based effective instruction methods: Concept Tests; Peer Instruction; Interactive Lecture demonstrations; Just in Time Teaching; Interactive Tutorials; Cooperative Problem Solving. Modeling. Problem Solving. Enhancing learning through peer, group and collaborative work. Cognitive Apprenticeship. Research-based curricula: Developing hands-on activities. Developing Interactive worksheets/Tutorials.

Unit III (12 hours)

Evaluating Conceptual Learning: Formative and Summative evaluation. Designing examinations. Types of questions: MCQ, Representation-translation questions, ranking tasks, context-based reasoning problems, estimation problems, qualitative questions, essay questions. Domain knowledge content surveys and concept probes (Mechanics, Electricity and Magnetism, Vectors, Quantum Mechanics etc).

Unit IV (16 hours)

Learning in the Lab: Students understanding of nature of scientific investigation and its influence on lab work. Student's perception of concepts of statistics, errors of observation, reliability and validity of observations; graphical representation of data and impact on performance. Developing Procedural and Conceptual Knowledge (PACK) in the Laboratory. Learning to design open-ended experiments and verify hypotheses. Assessment of performance.

Technology Enhanced Learning Environments: Appropriate use of technology. Developing Demonstration experiments and hands-on activities for conceptual learning. Sensor based Data Acquisition Laboratories. Integrating Simulations, Visualization, Video, Modeling for conceptual learning. Designing Technology Enhanced Active Learning. Future of classroom.

Course Learning Outcomes

Understanding theoretical framework of how students learn; familiarity with range of effective strategies for teaching-learning; evaluating and enhancing student's conceptual understanding of physics and problem solving abilities; developing effective learning in the lab and open-ended investigations; designing technology enhanced active learning environments;. Designing effective assessment and evaluation tools for student learning; developing innovative teaching-learning resources and curricula.

Suggested Readings

1. Teaching Introductory Physics, Arnold Arons (John Wiley and Sons, Inc., 1997)
2. Teaching Physics with the Physics Suite, Edward F. Redish (John Wiley and Sons Inc., 2003)
3. Teaching and Learning in the Science Laboratory, Dimitris Psillos and Hans Niedderer (Editors) (Kluwer Academic Publishers, 2002)
4. Understanding Basic Mechanics, Frederick Reif (John Wiley and Sons Inc., 1995)
5. Peer Instruction, Eric Mazur (Prentice Hall. 1997)
6. Physics by Inquiry. Vol. I and II., Lillian C. Mc Dermott (John Wiley and Sons Inc., 1996)
7. Workshop Physics. The Physics Suite. Priscilla, W. Laws (John Wiley and Sons Inc., 2004)
8. Real Time Physics Active Learning Laboratories. The Physics Suite, David R. Sokoloff, Ronld K. Thornton, Priscilla W. Laws (John Wiley and Sons Inc., 2004)
9. Activity Based Tutorials. The Physics Suite, Michael C. Wittmann, Richard N. Steinberg, Edward F. Redish and the University of Maryland Physics Education Research Group (John Wiley and Sons Inc., 2004)
10. Tutorials in Introductory Physics, Lillian C. Mc Dermott, Peter S. Shaffer and the Physics Education Research Group (John Wiley and Sons Inc., 2003)
11. Modelling in Physics and Physics Education, Proceedings of the GIREP Conference 2006. Ed van den Berg, Ton Ellermeijer and Onne Slooten. GIREP 2006.
12. Five Easy Lessons: Strategies for Successful Physics Teaching, Randall D. Knight.

Prerequisites for the course: Students should have taken Physics as one of the subjects in their Graduation (B.Sc.).