Department of Physics

Ramarkrishna Mission

Vivekananda Educational and Research Institute

Programme Outcomes, Programme Specific Outcomes and Course Outcomes

Master of Science (MSc) in Physics

MSc (Physics)

Program Outcomes

PO1. Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at ideas and decisions (intellectual, organisational, and personal) from different perspectives.

P02. Analytical Skill: To analyse from various branches of knowledge and arrive at independent conclusions.

PO3. Effective Communication: Communicate and comprehend clearly in person and through electronic media in English and to make meaning of the world by connecting people, ideas, books, media and technology.

PO4. Social Responsibility: To be conscious of the society and it's requirement, and contribute towards it.

PO5. Effective Citizenship: Demonstrate empathetic social concern and equity centred national development, and the ability to act with an informed awareness of issues and participate in civic life through volunteering.

PO6. Ethics & Morals: Recognize different value systems, understand the moral dimensions of decisions, and accept responsibility for them.

PO7. Environment and Sustainability: Understand the issues of environmental contexts and sustainable development.

PO8. Self-directed and Life-long Learning: Acquire the ability to engage in independent and life-long learning in the broadest context of socio-technological changes.

MSc (Physics)

Program Specific Outcomes

PSO1. Understanding the Scientific paradigm and its foundational philosophical principles.

PSO2. Understanding the foundational empirical principles of Physics.

PSO3. Understanding the epistemological source of knowledge in Physics and its connection with regards to theoretical analysis in Physics.

PSO4. Acquiring a rigorous knowledge in fundamental areas of Physics.

PSO5. Application of knowledge to real-life problems.

MSc (Physics)

Course Outcomes

Design and Fabrication Laboratory (PHY519)	CO1 Learn to apply creative skills and knowledge
	CO2 Learn to make technology accessible
	CO3 Learn to develop an open-ecology through sharing of ideas and knowledge
	CO4 Create an interdisciplinary/multidisciplinary platform for implementation of various ideas
	CO5 Train and empower the students in designing, assembling, fabricating and programming digital/microprocessor controlled systems, using a hands-on approach
	CO6 Learn to design cost-effective real-life devices/gadgets to benefit human beings and society as a whole
	CO7 Learn how to program the microprocessor hardware and analyse data
	CO8 Learn how to interface the microprocessor with a computer
	CO9 Learn how to interface the microprocessor hardware with sensors
	CO10 Learn how to interface control devices using the microprocessor hardware
	CO11 Design, fabricate and implement complete projects out of these microprocessor controlled hardware, preferably with some real-life application.
Computer Fundamentals and Computational Physics (PHY415)	CO1 Develop numerical, computational and analytical skills relevant to theoretical and experimental physics problem solving
	CO2 Acquire a hands-on approach towards computer hardware, software, clustering and networking
	CO3 Learn about Open Source philosophy and working in an Open Source environment
	CO4 Synchronise computational skills acquired with requirements of theoretical physics courses
	CO5 Work using Open Source operating systems (Linux/Unix) and software
	CO6 Learn programming skills in Shell scripting, C++, FORTRAN, Python, etc.
	CO7 Learn various Data Visualising skills, eg. GNUPlot, etc.
	CO8 Learn (scientific) Typesetting and presentation skills, primarily using LaTeX
	CO9 Application to various real-life problems
	CO10 Assemble & set up of fully functional PCs from scratch
	CO11 Construct cost-effective computer clusters for high-performance computing
Classical Mechanics (PHY411)	CO1 Understand Lagrangian Formulation
	CO2 Understand Hamiltonian Formulation
	CO3 Understand Canonical Transformations
	CO4 Understand Dynamics of a rigid body
	CO5 Learn Hamilton – Jacobi Theory

	CO6 Understand Mechanics of Continuous media
	CO6 Learn Theory of small oscillations
	CO7 Learn Classical Perturbation Theory
	CO8 Learn Non-linear dynamics and chaos
Quantum Mechanics I and II (PHY412 and PHY422)	CO1 Learn the principle of superposition
	CO2 Understand the postulates of quantum mechanics
	CO3 Learn about symmetries
	CO4 Study single particle formulation of non-relativistic quantum mechanics
	CO5 Learn the applications to physical systems
	CO6 Understand quantisation scheme and classical correspondence
	CO7 Learn Path integral formulation of quantum mechanics: free particle and particle in a well (perturbative approach)
	CO8 Learn Quantum theory of scattering, Approximation method in quantum mechanics
	CO9 Learn about quantum computation and quantum information theory
	CO10 Learn about Bell's inequalities
	CO11 Understand density matrix, reduced density matrix
	CO12 Entanglement, entanglement entropy (von Neumann and Renyi)
Mathematical Tools in Theoretical Physics I and II (PHY414 and PHY424)	CO1 Learn the Theory of complex variables
	CO2 Learn the Theory of linear ordinary differential equations
	CO3 Understand integral transforms
	CO4 Gain exposure to Special functions
	CO5 Gain knowledge of boundary value problems and Green's function
	CO6 Understand integral equations.
Classical Theory of Fields I: Electrodynamics (PHY413)	CO1 Learn about action principle formulation of relativistic particle
	CO2 Learn about relativistic formulation of Electromagnetic (EM) fields
	CO3 Learn about Action formulation of EM fields: Maxwell equations
	CO4 Learn about the vector potential: relativistic formulation
	CO5 Learn about Interaction of EM fields with currents: Noether's theorem
	CO6 Learn about interaction of charged particle with EM fields: Lorentz force equations, examples
	CO7 Learn about the Energy-Momentum tensor: Conservation and Poynting's theorem, ambiguities
	CO8 Learn about Vacuum EM waves: geometrical optics limit; polarisation, Stokes parameters and Poincare sphere,
	CO9 Learn about EM waves in media: Faraday rotation,
	CO10 Learn about EM potentials due to an arbitrarily moving charged particle, EM fields from the moving charges: radiation and Coulomb fields,
	CO11 Learn about Dipole radiator: Lamor's formula, radiated power spectrum,

	CO12 Learn principles of Synchrotron radiation: radiated power spectrum;
	CO13 Understand Polarisation,
	CO14 Learn about classical scattering by EM waves by charges: Rayleigh and Thomson scattering,
	CO15 Learn about Elements of multipole radiation: E1, E2 and M1 modes,
	CO16 Learn about radiation reaction and inconsistencies of the Maxwell theory.
Classical Theory of Fields II: General Relativity (PHY423)	CO1 Understand curvilinear coordinate systems in R3: Euclidean metric
	CO2 Understand invariance principles: Special Relativity and Gravity, Principle of Equivalence.
	CO3 Understand Pseudo-Newtonian derivation of redshift.
	CO4 Learn about curved spacetime: geodesics, Newtonian approximation.
	CO5 Learn about invariants in curved spacetime – scalar, vector and tensor fields, p-form fields, metric tensor.
	CO6 Understand parallel transport and affine connection, covariant derivative, geodesics, Lie derivative and isometries, Invariant measure, Invariant matter field, Belinfante energy-momentum tensor.
	CO7 Learn about external field problems – Stationarity and timelike Killing vector fields.
	CO8 Learn about gravitational redshift in stationary spectrum.
	CO9 Learn about spherically symmetric vacuum sptm: Schwarzchild Geodesics in Schwarzchild sptm : ISCOs and bounded orbits.
	CO10 Learn about light bending by a spherical star, Perihelion shift of Mercury.
	CO11 Learn about coordinate time and proper time, proper distance.
	CO12 Learn about curved spacetime geometry – Geodesic deviation, Riemann curvature tensor: components, invariants (Ricci and Kretchmann), Weyl tensor, Bianchi Identity.
	CO13 Learn about Einstein-Hilbert-Lorentz action and Einstein equation.
	CO14 Understand Newtonian approximation, Schwarzchild solution and properties of Gravitational waves, Introduction to relativistic cosmology.
Statistical Mechanics I (PHY426)	CO1 Get an overiew of thermodynamics;
	CO2 Objectives of statistical mechanics;
	CO3 Understand Microstates and macrostates;
	CO4 Understand Phase space and concept of an ensemble;
	CO5 Understand Liouville's theorem and the concept of equilibrium;
	CO6 Understand Ergodic hypothesis and postulate of equal a priori probability;
	CO7 Understand Microcanonical ensemble: Boltzmann's definition of entropy and derivation of thermodynamics;
	CO8 Understand the equipartition theorem;
	CO9 Understand Microcanonical ensemble calculations for a classical ideal gas;
	CO10 Understand the Gibbs paradox;

	CO11 Understand Canonical ensemble; Energy fluctuations in the canonical ensemble;
	CO12 Understand Grand canonical ensemble; Density fluctuations in the grand canonical ensemble;
	CO13 Understand Quantum statistical mechanics: Postulate of equal a priori probability and postulate of random phases; Density matrix; Ensembles in quantum statistical mechanics;
	CO14 Understand the ideal quantum gas: Microcanonical and grand canonical ensembles;
	CO15 Understand Fermi-Dirac and Bose-Einstein statistics; Bose-Einstein condensation.
Statistical Mechanics II (PHY516)	CO1 Understand basic introduction to phase transitions: first order and continuous;
	CO2 Understand critical phenomena: critical exponents and scaling hypothesis;
	CO3 Understand Ising model: exact solution in one dimension, mean-field approximation and calculation of critical exponents, Landau theory;
	CO4 Get an overview of probability theory: Law of large numbers and the central limit theorem; Random walk;
	CO5 Understand Brownian motion: Langevin and Fokker-Planck descriptions; Fluctuation-Dissipation theorem;
	CO6 Understand Markovian process;
	CO7 Understand Master equation;
	CO8 Understand the concept of steady states, detailed balance and equilibrium vs non-equilibrium;
	CO10 Get familiarized with a simple illustration using interacting random walks (simple symmetric and asymmetric exclusion processes).
Particle Physics I and II: Nuclear Physics (PHY522/523)	CO1 Understand charge, mass, constituents, binding energy and separation energy, level scheme, excited states, spin, parity and isospin, nuclear size and form factors, static electromagnetic moments.
	CO2 Understand Two-nucleon system: a) Deuteron: ground and excited states; electric quadrupole and magnetic dipole moments; non-central force and tensor interaction. b) Scattering states: n-p and p-p scattering at low energies; effective range and scattering length; singlet and triplet states; ortho- and para-hydrogen, charge independence of nuclear forces. c) Nucleon-nucleon scattering at higher energies d) Polarization in nucleon-nucleon scattering – l.s forces e) Exchange forces and saturation f) General properties of nucleon-nucleon forces;
	CO3 Learn about the Yukawa potential.
	CO4 Understand Complex– nuclear structure: a) need for nuclear models b) Fermi Gas model c) Static Liquid Drop model d) Shell Model e) Collective Model f) Unified Model.
	CO5 Understand about Nuclear Reactions: a) types of reactions and conservation principles b) Compound Nuclear Reactions – Resonances and the Breit Wigner formula c) Direct Reactions, Optical Model, Nuclear Fission – Bohr – Wheeler theory, Electromagnetic Transitions – Multipole transitions and selection rules.

Particle Physics I and II: Particle Physics (PHY522/523)	CO1 Learn about Relativistic kinematics: Mandelstamm variables; collision and decay kinematics; reaction thresholds; phase space, cross-section and decay formulae;
	CO2 Learn about types of interactions and their relative strengths;
	CO3 Learn about the discovery of positron, muon, pion, neutrino and other particles;
	CO4 Learn about Symmetry, conservation laws and Quantum numbers;
	CO5 Learn about classification of elementary particles;
	CO6 Learn about determination of quantum numbers of different particles;
	CO7 Learn about Hadrons – classification by isospin and hypercharge;
	CO8 Learn about Quarks, colour, Leptons and gauge bosons;
	CO10 Learn about Weak Interactions: a) phenomenology, conservation laws and selection rules b) Fermi theory of beta decay, V-A interaction c) non-conservation of parity d) Neutral Kaon decay – CP violation and regeneration e) Z and W+ and W- bosons,
	CO11 Learn about E-M interactions – the QED Lagrangian from gauge invariance principles.
	CO12 Understand Group Theory: Lie Group – SU(2), SU(3), SU(n) – Discrete Symmetry – C, P, T,
	CO12 Learn about QED – Feynman rules – Cross section and Decay rate calculations,
	CO13 Learn about Hadron Structure and Quark Model, Parton model, Deep Ineasltic Scattering – QCD , Weak Interaction phenomenology – Electroweak unification, Non-Abelean Gauge Theory – Standard Model
Condensed Matter, Atomic and Molecular Physics (PHY520)	CO1 Learn about Crystal structure — Lattice and basis, Examples of crystal structures, Direct and reciprocal lattice, Xray diffraction and crystal structure determination;
	CO2 Learn about theories on Specific heat of solids — Boltzmann, Einstein and Debye theories;
	CO3 Learn about theories of Elecrons in metals — Drude and Sommerfeld theories;
	CO4 Understand Lattice dynamics: Normal modes, phonons, anharmonic effects, lattice thermal conductivity;
	CO5 Learn about theories of Electrons in solids — Electrons in a periodic potential: Nearly free electron model, Bloch's theorem, Insulators, semiconductors, and metals: Band structures and optical properties;
	CO6 Learn aspects of Magnetism — Magnetic properties of atoms: Para and diamagnetism, Spontaneous magnetic order: Ferro-, antiferro-, and ferri-magnetism, Domains and hysteresis
	CO7 Be exposed to Spectroscopy: General definition and terminology, Multiplet structure and designation of spectral terms, coupling of two or more electrons in equivalent shells, spin orbit interaction and alkali spectra, Relativistic mass correction, Darwin term and hydroden fine structure. Zeeman and Stark effect.
	CO8 Learn about two electron systems, their wavefunctions, spectral terms.

	CO9 Study Many body theory, Hatree and Hatree Fock approximation, Configuration Interaction, Lamb shift.
	CO10 Learn about General structure of molecular energy levels, Born Oppenheeimer approximation. Rotational, vibrational, Rotational-vibrational and electronic spectra of diatomic molecules and their detailed structures.
	CO11 Understand Franck Condon principle and its implications, Raman spectra.
Quantum Field Theory I (PHY513)	CO1 Learn about Relativistic quantum mechanics and the Dirac equation and its solutions,
	CO2 Learn about Canonical quantisation: Free scalar field, electromagntic field, Dirac field,
	CO3 Understand Wick's Theorem, Correlation functions, Propagators for the scalar, Dirac and electromagnetic field.
	CO4 Learn the basis of interacting theories and Feynman diagrams.
Quantum Field Theory II (PHY523)	CO1 Learn about Interacting Quantum Field theories, Quantum electrodynamics (QED), Calculation techniques for Feynman diagrams of all major processes in QED,
	CO2 Learn about divergences in Quantum Field Theory, Removal of divergences, radiative corrections, explicit calculation of Lamb shift,
	CO3 Learn about Renormalisation theory, Wilson renormalisation group.
	CO4 Get exposure to Statistical field theory and applications to condensed matter physics, Two dimensional Ising model and gauge theories.
Advanced General Relativity and Astrophysics (PHY525)	CO1 Learn about Gravitational waves – Linearized General Relativity – Graviational waves in linearised GR – Energy radiated by gravitational waves – Detection of gravitational waves.
	CO2 Learn about White dwarfs – Astronomy basics – theormodynamics preliminaries – Degenerate electron gas – Equations of state – Chandrasekhar limit – Thomas-Fermi approximation approach to white dwarf – white dwarf cooling. Neutron stars – Histroy and formation – Structure and stability – Interior – Equations of state – Maximum mass – rotating neutron stars, pulsars.
	CO3 Learn about Black Holes – Penrose-Carter diagram of Minkowski and Schwarzschild spacetime – Reissner – Nordstrom blackhole – Majumdar-Papapetrou solutions – Kerr black hole – Kerr-Newman black holes – Geodesic congruences and the Raychaudhuri equation – Hamiltonian formulation of GR – Laws of black hole mechanics.
Cosmology (PHY524)	CO1 Learn about Comological observations, The expansion of the universe,
	CO2 Learn about Spacetime geometry, Comoving coordinates, Friedmann-Roberson-Walker (FRW) metric, Proper distances, Dynamics of a photon moving in FRW background, particle and event horizons.
	CO3 Learn about cosmological redshift. Hubble's law, Luminosity distances.
	CO4 Learn about the dynamics of expansion: Einstein field equations, Friedmann equation, Critical density, Matter dominated and radiation dominated expansion.
	CO5 Learn about galaxy Rrotation curves, Indirect evidence for dark-matter, discovery of accelerated expansion. Dynamics of dark energy, consmological constant.

	CO6 Learn about the Cosmic Mircrowave Background Radiation (CMBR), The equilibrium era, recombination and last scattering, the dipole aniotropy, The Synyaev Zel'dovich effect, Primary fluctuations in CMBR, Scahs-Wolfe effect, Harrison – Zel'dovich spectrum, Doppler fluctuations, Intrinsic temperature fluctuations, Integrated Scahs – Wolfe effect.
	CO7 Learn about the thermal History of early universe, Cosmological nucleosynthesis, Baryosysthesis and Leptosynthesis, cold dark matter.
	CO8 Learn about Comic inflation: flatness, horizon, monopole problem, Slow-roll inflation, Reheating. Comological perturbation theory, Origin of large scale structure.
Two-Dimensional Conformal Field Theory (PHY528)	CO1 Learn about the Conformal Group in D> 2 dimensions, Quasi primary fields, Conformal group in D=2 dimensions, Quasi primary and primary fields, secondary fields, 2-pt, 3-pt, f-pt correlation functions.
	CO2 Learn about Conformal ward identities, Stress energy tensor and conformal invariance, Mode expansion of Stress energy tensor, Virasoro Algebra, Conformal anomalies and Central charge, Operator product expansions.
	CO3 Learn about Kac determinants and Virasoro modules, briefly mentioned the minimal models, Crossing symmetry and conformal bootstrap method.
Advanced Condensed Matter Physics (PHY527)	CO1 Learn about Electron transport — Semi-classical equations, Bloch electrons in magnetic and electric fields, Hall effect and magneto-resistance, de Haas-van Alphen effect and Fermi surface determination;
	CO2 Learn about Semiconductors — Homogeneous semiconductors: carrier density, inhomogeneous semiconductors, carrier densities in a p-n junction, rectification;
	CO3 Learn about Dielectric properties — Screening, Thomas-Fermi and Lindhard expressions for dielectric constants, local field, optical properties, ferroelectrics;
	CO4 Learn about Mean field theory of ferromagnetic and antiferromagnetic transitions — Heisenberg model, spin waves;
	CO5 Learn about Superconductivity — Persistent current, Meissner effect and critical fields – type I and II superconductors, specific heat, Electron-Phonon interaction and BCS theory, Ginzburg-Landau theory, Superconducting tunneling-Josephson effect, high temperature superconductivity – brief discussion.

Doctor of Philsophy (PhD)
in Physics

PhD (Physics)

Program Outcomes

PO1. To gain a thorough a knowledge of the literature relevant to chosen field of research

PO2. To gain a comprehensive understanding of scientific methods and techniques applicable to the chosen field of research.

PO3. To be able to demonstrate originality in the application of knowledge in tackling and solving problems

PO4. To develop the ability to critically evaluate current research and research techniques and methodologies

PO5. To develop the skill to present one's own research and also scientific writing skills.

PhD (Physics)

Program Specific Outcomes

PSO1. To develop skills in developing new theories, and in planning and conducting experiments; developing practical research skills and learning new state of the art techniques used in research.

PSO2. Understanding the foundational empirical principles of Physics, specially in respective fields of research.

PSO3. Developing capability for independent exploration of research areas by identifying appropriate problems to work on.

PhD (Physics)

Course Outcomes

Research Methodology (PHY701)	CO1 Learn basic Computer Programming in FORTRAN/C++
	CO2 Learn Plotting using GNUplot
	CO3 Learn how to use LaTeX
	CO4 Learn basic Python programming
	CO5 Learn to use Mathematica
Advanced Quantum Field Theory (PHY712)	CO1 Understand interactions in the context of quantum field theory
	CO2 Understand Bosonic and fermionic systems in QFT.
Advanced Quantum Information Theory (PHY713)	CO1 Understand quantum correlations
	CO2 Learn the basics of Cryptography
	CO3 Learn the basics of quantum algorithms
Topical Course on Atomic, Molecular and Optical Physics (PHY705)	CO1 Gain understanding of one electron atoms, Dirac's theory of one electron atom
	CO2 Gain understanding of two electron atoms: Calculation of energy levels by perturbation and variational methods Doubly excited states
	CO3 Gain understanding of many electron atoms: Hartree Fock method
	CO4 Gain understanding of angular momentum coupling: LS, JJ and Intermediate coupling schemes, Spectral terms and Hund's rule, Multiplet structure.
	CO5 Learn about Laser Beams and Resonators:
	CO6 Learn about Nonlinear Optics and Atomic Laser Spectroscopy
Advanced Topics in Atomic and Molecular Physics (PHY706)	CO1 Understand the interaction of atoms with radiation:
	CO2 Understand the basics of molecular spectroscopy:
	CO3 Understand the basics of Microwave spectroscopy:
	CO4 Understand the basics of Infrared spectroscopy:
	CO5 Understand the basics of Electronic spectra
	CO6 Understand the basics of Raman Spectroscopy:
	CO7 Study about Intensities of molecular lines
	CO8 Classification of molecular terms and phosphorescence.
	CO9 Understand the Elements of ESR, NMR, NQR and molecular spectroscopy, chemical shifts.

Advanced Methodologies and Computational Aspects for Atomic Structure Calculations (PHY707)	CO1 Learn how to use employ numerical calculations and simulations in the context of atomic structure calculation
Advanced Cosmology (PHY702)	CO1 Learn about the elements of Standard (Friedman Robertson Walker) cosmology
	CO2 Learn about Cosmological observations
	CO3 Learn about cosmic microwave background radiation and its anisotropies
	CO4 Learn about Dark Matter
	CO5 Learn about Dark Energy
	CO6 Learn the principles of Cosmological Perturbation Theory
Advanced Particle Physics (PHY703)	CO1 Understand Spontaneous Symmetry Breaking
	CO2 Understand the Higgs Mechanism
	CO3 Gain familiarity with the Standard Model of Particle Physics
Topical Course on General Relativity (PHY704)	CO1 Understand the Einstein Equation
	CO2 Gain familiarity with the metric used for isotropic and homogeneous spacetime
	CO3 Learn about Gravitational Redshift
	CO4 Learn about the Schwarzchild metric
	CO5 Learn about bending of light by a spherical star
	CO6 Learn about perihelion shift of Mercury
Renormalization in Quantum Field Theory (PHY709)	CO1 Understand standard perturbative Renormalization techniques in scalar field theory: phi-4
	CO2 Understand standard perturbative Renormalization techniques in gauge theories: QCD
Topical Course on Statistical Physics (PHY710)	CO1 Understand kinetic theory
	CO2 Understand different ensembles (micro canonical, canonical, grand-canonical)
	CO3 Understand elements of quantum statistics (Fermi, Dirac, Bose)
Topics in Conformal Field Theory (PHY711)	CO1 Understand Conformal Transformations
	CO2 Understand Operator Product Expansion
	CO3 Understand the Conformal ward identities
	CO4 Learn about 3- and 4- point correlation functions
	CO5 Understand the computation of entanglement entropy in CFT..