SYLLABUS

for

PhD Course work in PHYSICS

2018-19

(Revised on 06.08.2020 following UGC guideline vide D.O.No.F.1-1/2018(Journal/Care) December 2019 and amended on 31.07.2021)

DEPARTMENT OF PHYSICS

COOCH BEHAR PANCHANAN BARMA UNIVERSITY

COOCHBEHAR

WESTBENGAL-736101

COURSE STRUCTURE

Paper Code	Paper Title	Credit	Class Hours	Full Marks
Course-1	**Research Methodology**	**4**	**60**	**100**
Course-2: Course-2A + Course-2B;(One course to be opted from Course-2A)				
Course-2A1	**High-energy Physics**	**2+2**	**30+30**	**50+50=100**
Course-2A2	**Relativistic Astrophysics and Cosmology**			
Course-2A3	**Experimental Techniques in Nuclear and Particle Physics**			
Course-2A4	**Experimental Techniques in condensed matter physics**			
Course-2A5	**Physics of Nanomaterials**			
Course-2A6	**Laser and non-linear optics**			
Course-2B	**Literature survey/Review Oral presentation on Ph.D. topics**			
CPE-RPE	**Research and Publication Ethics**	**2**	**30**	**50**
	Total	**10**	**150**	**250**

Course-1: Research Methodology

Group-A

Research Methods: Introduction to research, definition and characteristics of research, types of research, research methods and research methodology, importance of research, research process, criteria of good research, research ethics and plagiarism.

Literature Review: Uses of literature review, sources of information using internet, organization information, importance of literature survey.

Uses of internet in research works: Use of internet in searching research materials (research papers, books, etc.), paper downloading, and submission of papers in arXiv, use of SPRIES database, various websites for journals, knowledge of impact factor, citation of research paper.

Scientific report writing and presentation: Significance of report writing, different steps of it, type of reports, seminar presentations: oral and poster, abstract writing, thesis writing: its characteristics and format, references or bibliography.

References:

1. C R Kothari and GouravGarg , Research Methodology- Methods and Techniques (New age International)
2. Ranjit Kumar, Research Methodology, a step-by-step guide for beginners (3rd edition), SAGE publications.
3. Jan Jonker and BartjanPennink, The Essence of Research Methodology-A Concise Guide for Master and PhD Students in Management Science (Springer Publications).

Group-B

Computer Fundamentals and Programming with Numerical Analysis:

Computer fundamentals: Hardware and software, different operating systems, application programmes, some tips on PC maintenance and servicing of PC.

Common Applications: Working in a Linux environment, basic Linux commands, writing scientific documents with Latex, graphic and visualization, gnuplot; introduction to other useful software tools e.g. Mathematica, Matlab, Origin.

Programming using FORTRAN/ C (or C++) for numerical analysis: Basic Numerical Methods- Root finding (bisection and Newton-Raphson method), Interpolation techniques, Solution of ordinary differential equations (Euler and Runge-Kutta methods). Numerical integration (Trapezoidal and Simpson's method), numerical differentiation, diagonalization and inverse of symmetric and non-symmetric matrices, Eigenvalues and eigenvectors.

Statistics and treatment of experimental data: Data acquisition system, error propagation, curve fitting, least square method, Sampling and parameter estimation, the maximum likelihood method. Analysis of a time series and search for periodicity. FFT (Fast Fourier transformation) and power spectrum;Monte Carlo simulation

References:

1. Numerical methods for Scientific and Engineering Computation: M.K.Jain, S.R.K.Iyengar and R.K.Jain. (Wiley Eastern Limited),
2. Fortran 77 and Numerical Methods: C.Xavier (New Age International Publishers),
3. Techniques for Nuclear and Particle Physics Experiments, A How to approach: W.R.Leo (Narosa Publishing House)
4. Numerical Recipes: W.Press et.al, (Cambridge University Press).
5. Data reduction and error analysis for the Physical Sciences, 3e, Philip R Bevington& D. Keith

Course-2

Course-2A1: High-energy Physics

Introduction of high energy physics: Evidence for 4 fundamental interactions, leptons and hadrons,historical introduction to particle zoo, relativistic kinematics, the Gell-Mann eightfold way, quark model, construction of hadronic wave functions, magnetic moment of the neutron, statistics of baryons & concept of colour; discovery of weak interactions, Fermi theory. IVB hypothesis, parity violation, mass problem, and decay. Standard model of electroweak interaction, Minimal Super-symmetricStandard Model(MSSM), Neutrino masses and mixing angles. GUT and string theory.

Symmetries: Lie groups, Lie algebra, root and weight diagrams, Young's tableau, SU(2)and SU(3) groups. Discrete symmetries, parity, charge conjugation, and time reversal – CPTtheorem. Noether's theorem and conserved currents. Gauge theories, abelian and non-abeliangauge invariance, spontaneous symmetry breaking and Higg's mechanism, Goldstein theorem, Ginzburg-Landau theory, construction ofthe Glashow-Salam-Weinberg model.

Quantum electrodynamics: Elements of Dirac's theory. Free field theory; scalar, spinorand vectors fields; covariant commutation relations and Feynman's propagators. Interactingfield theory; covariant perturbation theory, S-matrix, Wick's theorem, cross-section and decay rates; spin sum and averaging; Feynman rules and graphs for QED and QCD. Parton Model, Lepton-lepton scattering; Moller scattering, Bhabha scattering, Compton scattering;electron – nucleus scattering, QCD-evolution equations.

Cosmic Rays: Review of theories of origin – solar, galactic and extragalactic cosmic rays. Supernovae origin, GZK cutoff. Topdown models of EHE cosmic ray origin.

References:

1. *David Griffiths, Introduction to elementary particles, Wiley-VCH publications,2004*
2. *S. Coleman, Aspects of Symmetry Cambridge University Press, 1985*
3. *T. D. Lee,Particle Physics and Field Theory, Harwood, 1981.*
4. *F. Halzen, A.D. Martin, Quarks and Leptons, Wiley, 1984.*

5. *TodorStanev, High energy cosmic rays, Springer publications,2004*

Course-2A2: Relativistic Astrophysics and Cosmology

1. Space-time: the space-time interval, the metric, Lorentz transformations, space-time diagrams, Tensors.
2. Curvature: covariant derivatives and connections, connection coefficients, Christoffel connection, parallel transport, affine parameters, Riemann curvature tensor, symmetries of the Riemann tensor, Bianchi identity, Ricci and Einstein tensors,Weyl tensor
3. Gravitation: Principle of Equivalence, gravitational redshift, gravitation as space-time curvature, physics in curved space-time, Einstein's equations, Hilbert action, energy-momentum tensor again, Weak Energy Condition
4. Gravitational Radiation: Gravitational plane waves, polarizations, gravitational radiation by sources
5. The Schwarzschild Solution and Black Holes, Birkhoff's theorem, event horizon, black holes, Kruskal coordinates, formation of black holes, censorship, black hole thermodynamics
6. Cosmology: Homogeneity and isotropy, Robertson-Walker metric, Friedmann equations, cosmological parameters, evolution of the scale factor, redshift, Hubble's law.
7. Basic ideas on computational tools.

References:

1. *Robert M. Wald: General Relativity, Overseas Press (India) Private Limited*
2. *S. L. Shapiro and S. A. Teukolosky: Black Holes, White Dwarfs and Neutron Stars, Wiley-Interscience Publications.*
3. *A. P. Lightman, W. H. Press, R. H. Price and S. A. Teukolosky: Problem book in relativity and gravitation (Princeton University Press*
4. *S. Weinberg: Gravitation and Cosmology, John Wiley and Sons*
5. *H. Stephani: General Relativity, CUP.*

Course-2A3: Experimental Techniques in Nuclear and Particle Physics

Detectors and techniques for nuclear and high Energy physics: Interaction of radiations with matter, Interaction of electrons, photons, neutrons, muons and neutrinos with matter.

Basics of nuclear detectors : General properties of radiation detectors, Simplified detector model, Modes of detector operation, Pulse height spectra, Energy resolution, Detector efficiency, Working principle and properties of different types of detectors - Gas detectors, Scintillation detectors, Semiconductor detectors.

Basics of nuclear electronics: Pre-amplifier, Amplifier, Discriminators, Gate and delay generators, Analog to digital converter, Time to amplitude converter and the basics of data acquisition systems.

Experimental nuclear physics techniques and detectors: Charged particle spectroscopy and particle identifications, Gamma ray spectroscopy, Fast neutron spectroscopy and detectors related to the different techniques.General concept of building a high energy physics experiments Coverage and options, Tracking detectors, Calorimeters, Vertex detectors, Muon chambers, Neutrino detectors, Particle identification detectors in high energy physics.

References:

1. *Radiation Detection and Measurement, Glenn F. Knoll*
2. *Nuclear Radiation Detectors, S.S. Kapoor and V. Ramamurthy*
3. *Techniques for Nuclear and Particle Physics Experiments: A How-To Approach, William R. Leo*
4. *Experimental Techniques in High-energy Nuclear and Particle Physics, edited by Thomas Ferbel*
5. *Introduction to Experimental Particle Physics, Richard Clinton Fernow*

Course-2A4: Experimental Techniques in Condensed Matter Physics

Structure determination of solids: Crystal symmetry, Bravais lattice; transformation of crystal Lattice, point groups; space groups; simple application of group theory to symmetry of crystals; space group determination; rotation and Weissenberg photographs, Fourier transform and its application; theory of structure analysis; Patterson synthesis and its application instructure determination; direct methods of crystal structure determination; diffraction of X-rays (XRD), electron diffraction and neutron diffraction forstructure determination, elementaryconcepts of surface crystallography, scanning, tunneling & atomic force microscopy.

Band theory of solids: Calculation of energy bands in solids; tight binding and LCAO methods, OPW method; cellular and augmented plane wave method; symmetry of energy bands, calculated energy bands; experimental study of electronic energy levels in solids, cyclotron resonance; anomalous skin effects; de Haas-van Alphen effect.

Semiconductors: Band structure of common semiconductors; effective mass theory, intrinsicand extrinsic semiconductor - statistics of electron-hole carriers and Fermi energy; dynamics of electrons and holes; generation and recombination processes; surface recombination;Shockley-Reed mechanism of recombination; life time of carriers; Hall effect

and HallCo-efficient for two carrier types, origin of positive Hall coefficient for metals, modification ofHall coefficient for velocity distribution of carriers.

.Films and surfaces:Preparation -Thermal Vapour Deposition, Chemical Vapour Deposition, laser ablation, Molecular Beam Epitaxy, study of surface topography by multiple beam interferometry, conditions for accurate determination of step height and film thickness Fizeau fringes, Electrical conductivity of thin films, difference of behaviour of thin films from bulk material, expression for electrical conductivity for thin film

References:

1.*Crystallography Applied to Solid State Physics, AR Verma and ON Srivastava 2nd edition, New age International publishers, 2001*
2. Solid State Physics, A J Dekker, MacmillanIndia Ltd, Bangalore, 1981.
3. Solid State Physics, C Kittel, V Ed, Wiley Eastern Ltd, 2013.
4. Elementary Solid state physics, MA Omar, Adison Wesley, New Delhi, 2000.
5. Solid state Physics, SO Pillai. New age international publication, 2002.
6. Solid state Physics, MA Wahab, Narosa publishing house, New Delhi., 1999.
7. Introduction to Solid state physics, L Azoroff, Tata McGraw Hill publications, 1993.

Course-2A5: Physics of Nanomaterials

Introduction: Origin of Nanotechnology, Nano-materials, classification of nanostructures – 1D, 2D and 3D confinement, Surface area to volume ration, Quantum confinement effect, band theory of nano-materials, Physical and chemical properties of nano-materials, applications of nano-structured materials.

Synthesis of nano-materials: Bottom-up approach and Top-down approach with examples. Various fabrication and synthesis techniques such as Ball Milling, Chemical bath Deposition, Electro-deposition, Sol-Gel, Physical Vapor Deposition, Pulsed Laser Deposition, Molecular Beam Epitaxy.

Characterization of Nano-materials: Diffraction techniques: X-ray Diffraction (XRD) – Crystalline, particle/crystallite size determination and structural analysis.
Microscopic techniques: Scanning Electron Microscopy (SEM)–Morphology, grain size and EDX; Transmission Electron Microscopy (TEM) –Morphology, particle size and electron diffraction, Selected Area Electron Diffraction (SAED).
Scanning probe techniques: Scanning Tunnelling Microscopy (STM) –surface imaging and roughness; Atomic Force Microscopy (AFM) -surface imaging and roughness; other scanning probe techniques.
Spectroscopictechniques: Photoluminescence –Emission (PL) and Excitation (PLE) spectroscopy; Infrared (IR), Fourier Transform infrared (FTIR) Spectroscopyand Raman spectroscopy; X-ray Absorption (XAS), UV-Visible spectroscopy.

Carbon nanostructures:Allotropes of Carbon, Graphene, Properties of Graphene, Applications of Graphene, Fullerenes, Fullerene synthesis and purification, Properties of fullerenes. Carbon nano-tubes, Structure, Types of Carbon nano-tubes, Synthesis of Carbon nano-tubes, Purification of Carbon nano-tubes,Properties of Carbon nano-tubes, Applications of Carbon nano-tubes.

References:

1. *Introduction to Nanotechnology, Poole & Owners, Wiley India Pvt Ltd, 2007.*
2. *Nanotechnology: A Crash Course, Raul J. Martin-Palma, AkhileshLakhtakia, SPIE Publications, 2010.*
3. *Handbook of Nanophysics – Principles and Methods: By Klaus D. Sattler; CRC Press, 2010*
4. *Nanostructures and Nano-materials: Synthesis, Properties, and Applications, Cao; World Scientific Publishing Company, 2011.*
5. *Introduction to Nano-science and Nanotechnology, Chattopadhyay & Banerjee, PHI Learning Pvt. Ltd., 2009.*
6. *Chemistry of Nano-materials: Synthesis, Properties and Applications, Rao, Muller &Cheetham, Wiley VCH.*

Course-2A6: Laser and non-linear optics

Review of fundamentals of laser action in a medium, Single and multimode oscillations: Multimode oscillations, single-line and single-mode oscillation, frequency pulling, Lamb dip and laser frequency stabilization; ultimate line width of the laser (limit to mono-chromaticity), laser spiking in time-dependent condition. Some laser systems: Gas laser, Nd:YAG, Dye laser, Semiconductor laser, Excimer laser,chemical laser, X-ray and gamma ray laser and its applications.

Q-switching and mode locking techniques:Q-switching, production of a giant pulse; methods ofQ-switching: Mechanical shutters, electro-optical shutters, acousto-opticQ- switches, shutter using saturable dyes, peak-power emitted during the pulse, giant pulse dynamics. Mode locking: Active and passive mode locking techniques, ultra-short laser pulses, Laser amplifiers.

Introduction to non-linear optical processes: Propagation of electromagnetic waves in non-linear optical media, Non-linear optical susceptibilities and Symmetry, Three waves mixing: second harmonic generation, phase matching techniques, efficiency, parametric mixing, amplification and oscillation, power considerations. Four wave mixing, Optical phase conjugation, Stimulated Raman Scattering, Electromagnetic theory of Stimulated Raman Scattering, Quantum mechanical description of Raman Scattering, Anti-Stokes scattering, Optical Kerr effect, Nonlinear Spectroscopy, Multi-photon processes, Self-focusing self induced transparency.

Devices: Photorefractive crystals, theory and application to imaging, Electro-Optic effect, Retardation, electro-optic modulators, acousto-optic materials and acousto-optic modulators, Magneto-optic effect, retardation and modulators. Quantum detectors, limits of detection systems, noise in optical detectors.

References:

1. *Non-linear optics, R.W. Boyd, Academic press, Elsevier, 2008.*
2. *Essentials of Lasers and Non-Linear Optics; Baruah; PragatiPrakashan; 2000.24*
3. *Handbook of Nonlinear Optics, R. L. Sutherland, 2003.*
4. *Nonlinear Optics; Nicolaas Bloembergen; World Scientific Pub Co Inc; 1996*
5. *Laser and Non-Linear Optics; Laud; New Age; 1991*
6. *Lasers; Anthony E. Siegman; University Science Books; 1986*
7. *Principles of Nonlinear optics, Y. R. Shen, A Wiley Inter-science Publication, 1984.*
8. *Essentials of Nonlinear Optics, Y. V. G. S. Murthy and C. Vijayan, Wiley.*

Course-2B: Literature survey/Review Oral presentation on Ph.D. topics (Marks:50)

CPE-RPE: Research and Publication Ethics

Course structure:

- The course comprises of six modules listed in table below. Each module has 4-5 units:

Modules	Unit title	Teaching hours
Theory		
RPE01	Philosophy and Ethics	4
RPE02	Scientific Conduct	4
RPE03	Publication Ethics	7
Practice		
RPE04	Open Access Publishing	4
RPE05	Publication Misconduct	4
RPE06	Database and Research Metrics	7
Total		30

Syllabus in detail:

THEORY

- **RPE 01: PHILOSOPHY AND ETHICS (3 hrs.)**

1. Introduction to Philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgments and reactions

- **RPE 02: SCIENTIFIC CONDUCT (5 hrs.)**

1. Ethics with respect to science and research

2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication and Plagiarism (FFP)
4. Redundant Publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data

- **RPE 03: PUBLICATION ETHICS (7 hrs.)**

1. Publication Ethics: definition, introduction and importance
2. Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

PRACTICE

- **RPE 04: OPEN ACCESS PUBLISHING (4 hrs.)**

1. Open access publications and initiatives
2. SHERPA / RoMEO online resource to check publisher copyright & self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

- **RPE 05: PUBLICATION MISCONDUCT (4 hrs.)**

A. Group Discussions (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools (2 hrs.)

Use of plagiarism software like Turnitin, Urkund and other open source software tools

- **RPE 06: DATABASES AND RESEARCH METRICS (7 hrs.)**

A. Databases (4 hrs.)

1. Indexing databases
2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics (3 hrs.)

1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
2. Metrics: h-index, g index, i10 index, altmetrics

References:

1. Bird, A. (2006).*Philosophy of Science,* Routledge.
2. MacIntyre, Alasdair (1967). *A short History of Ethics.* London.
3. P. Chaddah, (2018), Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN: 978- 9387480865.
4. National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). *On Being a Scientist:A Guide to Responsible Conduct in Research:Third Edition.* National Academies Press.
5. Resnik, D. B. (2011). What is ethics in research and why is it important. *National Institute of Environmental Health Sciences*, 1 – 10. Retrieved from https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm
6. Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489(7415), 179-179. https://doi.org/10.1038/489179a.
7. Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (2019), ISBN: 978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf