SYLLABUS

For

M. Phil in PHYSICS

(Effective from the academic session 2020 – 2021 and onwards)

PHYSICS DEPARTMENT

THE UNIVERSITY OF BURDWAN

www.buruniv.ac.in

M. Phil in Physics

Course Structure

Semester	Course code	Course name	Credit	Marks
I	MPHIL 101	Research Methodology	4	50
	MPHIL 102	Research & Publication Ethics	2	25
	MPHIL 103	Advanced Physics	4	50
	MPHIL 104	Term paper(s) & Seminar presentation (s)	4	50 (25+25)
		Total	14	175
II	MPHIL 201	Advanced Theoretical Physics	4	50
	MPHIL 202	Spectroscopy and Communications	4	50
	MPHIL 203	Term paper(s) & Seminar presentation (s)	4	50 (25+25)
		Total	12	150
III & IV	MPHIL 301	Dissertation	12	150
	MPHIL 401	Viva voce	4	50
		Total	16	200

1 Credit: 1 class per week

SEMESTER I

Course code: MPHIL 101

Research Methodology

Unit I: Research methodology in general

Meaning of scaling; Scales of measurement. Uncertainties in measurements, single-variable and multivariable function, propagation of errors, Analysis distribution, some statistical ideas, distribution and probabilities, continuous distribution, normal distribution, Gaussian distribution. Confidence limits and error bars. Least square fitting of some complex functions.

Concept of research; Objective and motivation in research; Significance, Types and process of research; Different approaches of research; Salient points of good research; Research methodology in basic science. Writing literature review, effective poster presentation; writing scientific papers, Internet in scientific research. Procedure for obtaining a patent.

Unit II: Computer applications in scientific research

Introduction to Linux and FOSS software. Basic shell commands. Introduction to compiling and linking. Using IDE for coding.

Typesetting with LaTeX: Concept of LaTeX and contrast with word processors: WYSIWYG vs WYSIWYM. LaTeX Document Structure. Text and paragraph formatting, Lists and Tables. Math models. Figure environment and importing graphics. Review of procedural programming in C.

Sequential, selection and loop structure; Pointers and arrays; Functions and subprograms; Structures, unions and enumerated types; Data structures and linked lists. Introduction to procedural programming in python

Basics of the python interpreter. Setting up and using python Modules, functions and lambdas in python. Variables and scoping.

Basic python objects and native datatypes: Basic arithmetic operations and operators. Control flow and decision control.

Lists in python. Errors and exceptions. Scientific computing in python using numpy/scipy, matplotlib.

Unit III: Some Pedagogical aspects of Physics

Mathematical Methods: Integral transforms with applications. z-transform and its applications.

Landau theory of phase transition. Continuous and first order phase transition with examples. Order parameter and critical exponent. The concept of fluctuations in statistical physics.

Some exactly solvable problems in Quantum Mechanics: Harmonic oscillator, Hydrogen Atom. Rotation and Angular Momentum, Rotation of spin states. Scattering – Born Approximation, Partial Wave Analysis, Scattering of Identical Particles. Interaction of atoms with Radiation.

One-electron atom – Characteristics, Fine structure and hyperfine structure. Many Electron Atoms – Characteristics and Approximations; Introduction to Molecular Orbitals. Determination of Molecular Structure – Experimental procedures and theoretical methods.

Course code: MPHIL 102

Research & Publication Ethics

- **PHILOSOPHY OF ETHICS**

1. Introduction of philosophy: Definition, Nature and scope, concept, branches
2. Ethics: Definition, moral philosophy, nature f moral judgements and reactions

- **SCIENTIFIC CONDUCT**

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification an, Fabrication, and Plagiarism (FFP)
4. Redundant publications: Duplicate and overlapping publications, Salami Slicing
5. Selective reporting and mis-presentation of data

- **PUBLICATION ETHICS**

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 contributor ship.
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

- **OPEN ACCESS PUBLISHING**

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

- **PUBLICATION MISCONDUCT**

A. Group discussion

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

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

DATABASES AND RESEARCH METRICS

A. Databases

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

B. research Metrics

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

Course code: MPHIL 103

Advanced Physics

Unit I

Basic properties of linear vector space, angular momentum in quantum mechanics, angular momentum eigenstates and their addition in Hilbert space, Wigner Eckert theorem and its applications. Relativistic wave equations: the Klein-Gordon and the Dirac equations and related physics. Basic aspects of quantization of fundamental fields. Second quantization as applied to non-relativistic many-body systems.

Unit II

Bloch electrons and band structure, Band electrons in a magnetic field. Thermodynamic functions of a vibrating solid in the harmonic approximation, an-harmonic interaction. Boltzmann transport equation, Electron-phonon interaction, Kubo formula for electrical conductivity. Hatree-Fock approximations for the electron gas, Plasma Oscillations. Spin Hamiltonian. Heisenberg Model, Indirect Exchange and Superexchange, Spin waves and magnons, Spin waves in Antiferromagnets. Ginzburg-Landau theory of Superconductivity, Functional masterials, GMR, CMR.

Unit III

Brief discussion on crystal symmetries, Point groups and space groups. Structure factor determination of some crystal systems. Electron diffraction. Neutron diffraction.

Unit IV

Cosmology: Some aspects of FRW Universe, Red shift, Velocity – distance relation and Hubble's law, Luminosity distance, Problems of standard cosmology, Early Universe: Inflationary paradigm, Slow roll technique, Examples of Inflationary models. Dark matter and Dark energy.

Astrophysics: Gravitational collapse, White Dwarfs, Chandrasekhar mass limit, Neutron stars, pulsars, Black holes, Schwarzschild and Kerr Black holes, event horizon, ergosphere and i.r.s.

Unit V

Nonlinear Electronic circuits and Systems: Emulating nonlinear differential equation with electronic circuits. Chaotic electronic circuits.

Antenna basics: Dipole antenna, Power propagation.

μwave vacuum tube devices:

Reflex Klystron and multi cavity Klystron, TWT Amplifier, Magnetron.

Microwave solid state devices:

Tunnel Diodes, Gun diodes, varactor diodes, HEMT, IMPATT diode.

Characteristics of optical emission, LED: Power and quantum efficiency calculation, Structure of LED, Hetero-junction LED, Photo diode: PIN and APD photodiode, and hetero junction diode, Phototransistor, Photo conductors, Quantum well laser, opto-couplers, Shot noise.

Fiber optics:

Optical fibre, Fiber materials, Drawing process, step and graded index fibres, ray propagation, Modes in optical fibres: multi-path dispersion, single mode fibre- working principle, Multimode fibre, Group velocity dispersion, Directional coupling, Optical soliton.

Optical amplifiers and nonlinearity:

Semiconductor Optical Amplifier, XGM, SPM, XPM, Four wave mixing. EDFA.

Unit VI

Nonlinear Optics and application:

Nonlinear optical effects; Second and third order nonlinearities; Harmonic generation; Generation of tunable radiation (Sum, Difference Frequency and Optical parametric oscillators); Light detection and ranging (LIDAR), Optical phase conjugation; Generation, detection and measurement of ultrafast pulses.

Nonlinear Crystals:

Growth techniques and properties of different UV to IR transmitting crystals.

Laser Cooling and BE Condensation:

Principle of laser cooling and trapping, optical molasses, cooling below Doppler limit, magnetic trapping, applications.

Unit VII

Shell Model: Mean field concept, Two-state and multistate mixing, Residual interaction, Pairing correlation, M-scheme calculation, Configuration mixing. Shell model spectroscopy and spectrum of ^{18}O and ^{19}O. Many-particle shell model.
Collective Model: Qualitative discussion on vibrational, rotational and Nilsson models. Interacting boson model - basic ideas, Hamiltonian, group chains and eigenvalues.
Nuclear Structure at extremes of stability: Theoretical concepts and extrapolations, Drip line physics.

Course code: MPHIL 104

Term paper(s) & Seminar Presentation(s)

Distribution of marks

Preparation:	25
Seminar Presentation & Viva voce:	25

Reference Books

1. Principles of Quantum Mechanics, R. Shankar, Springer (1994)
2. Quantum Mechanics, Leonard I. Schiff, McGraw –Hill Kogakusha Ltd. (1968)
3. Relativistic Quantum Mechanics, James D. Bjorken and Sidney D. Drell, McGraw Hill Book Company (1965)
4. Quantum Field Theory, Lewis H. Ryder, Cambridge University Press (1985)
5. Quantum Theory of Many Particle Systems, John D. Walecka and Alexander L. Fetter, McGraw-Hill
6. A First Book of Quantum Field Theory – A. Lahiri and P. B. Pal, Narosa Publishing House (2001).
7. Optoelectronics and Fiber Optic Communication, D C Sarkar and C K Sarkar, New Age.
8. Photonics : A Yariv and P Yeh. Oxford.
9. Optical Electronics : By Ghatak and Thyagrajan , Cambridge University Press.
10. Sensors and Transducers (2 nd Edn), D. Patranabis, PHI Learning Pvt. Ltd., New Delhi 2009.
11. Communication Electronics, Control Theory, High frequency Devices: Electronic Communication Systems, Kennedy, TMH.
12. Communication systems, Lathi, Oxford Electronic communication Systems.

13. Electronics Communication, Roddy and Coolen, Pearson.
14. Microwave Devices and Circuits, Liao, Pearson.
15. Microwave, Sisodia and Gupta, New Age.
16. Solid State Laser Engineering: W Koechner (Springer)
17. Handbook of Nonlinear Optics: R L Sutherland (Marcel Dekker, Inc.)
18. Modern Spectroscopy: J M Hollas (Wiley)
19. R.F. Casten: Nuclear Structure from a Simple Perspective (Oxford University Press)
20. K. Heyde: Basic Ideas and Concepts in Nuclear Physics (Institute of Physics Publishing)
21. D.J. Rowe and J.L. Wood: Fundamentals of Nuclear Models (World Scientific)
22. S.N. Mukherjee: Elements of Nuclear Theory (CBS Publishers)
23. S.S.M. Wong: Introductory Nuclear Physics (PHI)
24. C R Kothari, Research Methodology: Methods and Techniques, New Age International (P)Ltd. (2010) , New Delhi
25. Inderpal Singh, Research Methodology and Statistical Methods, Kalyani Publishers, Ludhiana.
26. Textbook of Research Ethics, By Sana loue, https://link.springer.com
27. Handbook of Research Ethics & Scientific Integrity, R. Iphofen, Springer (2019).

SEMESTER II

Course code: MPHIL 201

Advanced Theoretical Physics

Unit I:

Elementary representation of three-dimensional rotational group. Crystal field splitting of atomic energy levels. Group theoretical matrices-element theorem. Selection rules and parity. Symmetry and molecular orbitals.

Unit II

Bloch electrons and band structure; Band electrons in a magnetic field; Phonons: thermal properties; An-harmonic interaction. Integer quantum Hall effect. Landau Diamagnetism, the de Haas-van Alphen effect. Hubbard model: basic features. Magnetic neutron scattering; Band magnetism and Stoner theory. Bogoliubov quasiparticles; Bosons: superfluidity.

Unit III

General Relativity: Einstein's law of gravitation, Circular geodesic in Schwarzschild space-time – minimum radius, gravitational red shift, Schwarzschild, Kerr and Kerr-Newmann Black hole thermodynamics.

Astrophysics: Saha equation of thermal ionization and its consequences in astrophysics, Jean's criteria for star formation, Lane-Emden equation and its applications. Aceration disks around black holes and neutron stars.

Cosmology: FRW Universe, field equations, models of the universe for K = 0, +1, -1, Big Bang. Olber's paradox.

Unit IV

Elements of String Theory: Introduction-String theory as a unified theory of physics. Special relativity and extra dimensions. Electromagnetism and gravitation in various dimensions. Nonrelativistic strings. Relativistic point particle. Relativistic strings. String parametrization and classical motion.

World sheet currents. Light-cone relativistic strings. Light cone fields and particles. Relativistic quantum point particle. Relativistic quantum open strings. Relativistic quantum closed strings. A look at relativistic superstrings.

Course code: MPHIL 202

Spectroscopy and Communications

Unit I

Laser Spectroscopy

Gas Laser: (i) molecular gas lasers- CO_2laser (ii) ionic gas laser – Ar^+ laser, (iii) Metal vapour laser.

Solid State Laser: (i) Nd:YAG laser, (ii) Tunable solid state laser: Ti:sapphire laser; Alexandrite laser

Chemical Laser: HF laser,

Other laser sources: Fibre laser**,** Free electron laser.

Stimulated Raman spectroscopy, Coherent anti-Stokes Raman scattering spectroscopy, Hyper Raman spectroscopy, Opto-galvanic spectroscopy, Photo-acoustic spectroscopy, Two-photon and multi photon absorption spectroscopy, Femto-second spectroscopy, Cavity ring-down spectroscopy, Tera-hertz spectroscopy.

Unit II

X-Ray spectroscopy

Structure of metals, alloys, ceramics. Microstructural characterization employing x-ray diffraction. Line profile analysis.

X-ray dispersion theory. Modified Bragg's law. Auger electron spectroscopy, X-ray photoelectron spectroscopy, Soft X-ray spectroscopy. Magnetic spectra of photoelectrons.

Unit III

Nuclear Spectroscopy

High Purity Germanium detectors (HPGe), Compton-suppressed Ge detectors, Composite Ge detectors, Very large detector arrays using segmented, composite and tracking detectors – GAMMASPHERE, Indian National Gamma Array (INGA), TIGRESS and AGATA spectrometers. Modeling of a detector array.
Gamma-gamma Coincidence method. Energy and Timing Calibration of detectors. Placement of new transitions in the level scheme – illustration with examples.
Measurement of Spin - Angular distributions, Angular Correlations and DCO ratio.

Unit IV

Communications

Pulse modulation : PAM, transmission of PAM signal, different forms of pulse modulations, Pulse amplitude modulation, pulse duration and position modulations, PCM, Quantization noise .
Pass band, digital modulation – ASK, FSK, PSK, MSK, CPFSK, QPSK, DPSK .
Antenna basics**:** Parameters, patterns, beam area, beam efficiency, directivity D and gain G, directivity and resolution, antenna aperture, effective height, radio communication link, fields from oscillating dipole, linear, elliptical and circular polarization, pointing vector. Different types of antenna.
Phase-locked loops (PPLs): analog PLLs, locking range and tracking range, Transfer functions, Digital phase-locked loops, Systems equations. Nonlinear phenomena in PLLs. Concept of phase locking in biological systems.

Optical fiber communication: Modal propagation of light, Dispersion (Multimode, Material, Wave guide), non-linear optical fiber, fiber sensor, EDFA, directional coupler.

References:

1. K.M. Varier: Nuclear Radiation Detection, Measurement and Analysis (Narosa)
2. G. Gilmore: Practical Gamma-ray Spectrometry (Wiley)
3. J. Cerny: Nuclear Spectroscopy and Reactions – Part C (Academic Press)
4. J. Eberth, J. Simpson, From Ge(Li) detectors to gamma-ray tracking arrays - 50 years of gamma spectroscopy with germanium detectors, Prog. Part. Nucl. Phys. **60**, (2008) 283, and references therein.
5. R. K. Bhowmik lectures - http://symposium.vecc.gov.in/serc06/public_html/lecture/
First Course in String Theory, Barton Zwiebach, Cambridge University Press (2004)
6. String theory and Einstein's Dream, Ashoke Sen, www.hri.res.in/~sen/current2.pdf
7. Condensed Matter Physics – Michel P. Marder.

Course code: MPHIL 203

Term paper(s) & Seminar Presentation(s)

Distribution of marks

Preparation:	25
Seminar Presentation & Viva voce:	25

SEMESTER III & SEMESTER IV

Course code: MPHIL 301

Dissertation

Course code: MPHIL 401

Viva-voce