SYLLABUS

Ph.D. Course work

(*w. e. f. academic year 2025-2026 and onwards)*

Ref: SPPU Circular No. 195/2025

PGS/1860, Date: 23/07/2025

Department of Physics

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Syllabus for Ph.D. Course work: Physics

(*w. e. f. academic year 2025-2026 and onwards*)

Ref: Circular No. 195/2025; PGS/1860, Date: 23/07/2025

http://sppudocs.unipune.ac.in/sites/circulars/MPhilPhDAdmission%20Circulars/Ph.D.%20Regulations%20SPPU_11072024.pdf

And

http://sppudocs.unipune.ac.in/sites/circulars/MPhilPhDAdmission%20Circulars/195.2025_23.07.25_23072025.pdf

1.0 Preamble

The Ph.D. course work is a pre-requisite for all Ph.D. programmes. This syllabus is applicable to all research centres offering Ph.D. programmes in Physics affiliated to Savitribai Phule Pune University. The total credit requirement for the Ph.D. programme is **16 credits**.

I. The total number of credits for Ph.D. shall be 16
II. The course work will be treated as pre-requisite for Ph.D. programmes.
III. The Ph.D. course work shall consist of the following components, structure and the respective credits.
IV. All other rules and regulations regarding the course work shall be adhered as per Savitribai Phule Pune University (SPPU), Pune and University Grants Commission (UGC), New Delhi.

2.0. Ph. D. Course Structure for Physics

The syllabus will be applicable to all the research centres offering Ph.D. programme in Physics affiliated to the Savitribai Phule Pune University. The course work shall be of 16 credits-

Sr. No.	Course Code	Course Name	Credits	No. of Hours
1.	**Phy-Ph.D. 001**	Research Methodology	**04**	**60**
2.	**Phy-Ph.D. 002**	Attending Seminar/Conference/Workshop (National/International)	**01**	**15**
3.	**Phy-Ph.D. 003A**	Subject Specific Advanced Course: Fundamentals of Physics Revisited	**04**	**60**
	Phy-Ph.D. 003B	Subject Specific Advanced Course: Advanced Experimental/Computational Techniques	**04**	**60**
4.	**Phy-Ph.D. 004**	Research & Publication Ethics *Research centre can have their own course to be run and evaluate (Circular No.286/2024/PG Admission/3813, Date:29/11/2024* OR *Research centre can adopt a payment basis Publication ethics online course run by the Centre of Publication Ethics*	**02**	**30**
5.	**Phy-Ph.D. 005**	Pedagogical Training/Industrial Visit Report/Assessment Statement	**01**	**15**
		TOTAL	**16**	**240**

Course structure as per University circular available on following link:

http://sppudocs.unipune.ac.in/sites/circulars/MPhilPhDAdmission%20Circulars/Ph.D.%20Regulations%20SPPU_11072024.pdf And

http://sppudocs.unipune.ac.in/sites/circulars/MPhilPhDAdmission%20Circulars/195.2025_23.07.25_23072025.pdf

3.0 Detailed Syllabus

COURSE 1. Research Methodology (Phy-Ph.D. 001)

Detailed Course Descriptions

Course 1: Research Methodology (Phy-Ph.D. 001)

Credits: 4 | Hours: 60

Objective: To impart knowledge of scientific research methods, quantitative tools, data analysis, proposal writing, and technical communication. This course is designed by the university for all faculties, which is available on the following link on the university website.

http://collegecirculars.unipune.ac.in/sites/documents/Revised%20PhdMPhilSyllabus2020/Research%20Methodology%20Revised%20Syllabus%20(%20Ph.D.%20Course)_08.092020.pdf

Purpose - This course is one of the common courses that will train the Ph.D. student to do research efficiently.

Need of the course - It is observed that most of the Ph.D. entrants are not aware of the philosophy behind the research. Students face many questions such as why a research study has to be undertaken, how the research problem has to be defined, in what way and why the hypothesis has to be formulated, what data has to be collected, which method/technique has to be adopted, why specific technique of analyzing data has to be used and a host of similar other questions while performing their research. The present course will facilitate the students to address these issues which help them to execute quality research.

Structure of the course – The course is structured into four different modules. The contents are largely case based so that student understands the practical workability of the course.

Modules

1. **Fundamentals of Research**
    - Meaning, objectives, and types of research
    - Research methods vs. methodology
    - Scientific method; inductive and deductive reasoning
    - Ethics in research, plagiarism, Intellectual Property Rights (IPR)
2. **Research Design & Literature Survey**
    - Defining research problem, hypothesis formulation
    - Literature review: Scopus, Web of Science, Google Scholar
    - Identifying gaps and setting objectives
    - Case-study-based topic selection
3. **Data Collection & Analysis**
    - Data collection Methods
    - Sources of data: primary, secondary, qualitative, quantitative
    - Statistical analysis; error & uncertainty in measurements
    - Noise analysis, curve fitting, use of statistical software
4. **Technical Writing & Proposal Preparation**
    - Research papers, theses, reports, patents
    - Referencing styles (APA, IEEE, MLA)
    - Research proposal writing for funding (DST, SERB, DRDO, ISRO, UGC)
    - Presentation skills (oral/poster)

References: Kothari (Research Methodology), Bevington (Data Analysis), Taylor (Error Analysis), Jana (Scientific Research), Kuhn (Structure of Scientific Revolutions). Mandel, J. *The Statistical Analysis of Experimental Data*.

Mode of examination

The internal examination of the course will be separately conducted. The examination mode is decided by the instructor of that course.

The external examination will be conducted at the time of 4th half yearly progress review. The student's implementation of various aspects in research methodologies will be checked.

Course 2: Phy-Ph.D. 002 - Seminar/Conference/Workshop (1 Credit, 15 Hours)

Purpose: To provide exposure to the national/international scientific community and contemporary research trends.

Requirement: Mandatory attendance and participation in at least one National or International Seminar, Conference, or Workshop.

Mode of Examination: Evaluation based on certification of attendance and a report/presentation on the experience.

COURSE 3 Course Code: Phy-Ph.D. 003A and 003B Title- Subject specific advanced level course

Phy-Ph.D. 003A: Fundamentals of Physics revisited (04 credits)

Phy-Ph.D. 003B: Advanced Experimental Physics (04 credits)

Credits: 08 *(04 each; 60 + 60 hours)*

Subject - Phy-Ph.D. 003A: Fundamentals of Physics revisited (04 credits)
Purpose – To revise the fundamentals of Physics useful for research
Need of the course – For doing research in any advanced topics it is essential to have thorough background of basics related to the subject. This course is designed in such a way to train a student to meet the essentials of the advance course.

Structure of the course – The course consists of seven modules related to basic physics namely Mathematical methods in physics, Classical mechanics, Electrodynamics, Quantum mechanics, Statistical mechanics, Nuclear and Particle physics and Atoms, Molecules and Solids.

Sr. No.	Contents	No of Hours
1	**Mathematical Methods in Physics:** Application of vector calculus in classical mechanics and electrodynamics. Vector spaces and operator algebra, matrices and their application in quantum mechanics, Linear first order and second order differential equations in physics, Fourier series, Fourier and Laplace transforms, Complex analysis its applications in evaluating integrals.	8
2	**Classical Mechanics:** Lagrange's and Hamiltonian Formalisms, Conservation theorems and symmetry properties, Two- body central force problem- reduction to one body problem, scattering in a central force field. Small oscillations, orthogonal transformations, Eulerian angles, Rigid body motion.	8
3	**Electrodynamics:** Laplace and Poisson equations, boundary value problems, method of images, Electrostatics in dielectric media, Ampere's theorem. Bio-Savart law, electromagnetic induction, Maxwell's equations in free space and in linear isotropic media, Boundary conditions on fields at interfaces, scalar and vector potentials. Gauge invariance. Electromagnetic waves - reflection and refractions, dispersion, interference, coherence, diffraction, polarization, electrodynamics of charged particles in electric and magnetic fields. Radiation from moving charges and from a dipole, retarded potentials and fields.	8
4	**Quantum Mechanics:** One dimensional problems, Harmonic oscillator, hydrogen atom, spherically symmetric potential: bound states and scattering states, angular momentum algebra, time independent and time dependent perturbation theories, WKB approximation, identical particles and symmetry, quantization of electromagnetic field (Coulomb gauge), Kramers-Heisenberg formula, Thomson, Raleigh and Raman scattering	8

5	**Statistical Mechanics:** Probability theory, statistical description of macroscopic systems, phase space, ensembles, partition function, laws of thermodynamics, thermodynamic potentials and Maxwell's relations. Chemical potential, free energy and connection with thermodynamic quantities. Ideal gas, Classical and quantum statistics, degenerate electron gas, Bose-Einstein condensation, realization of Bose-Einstein condensate in the laboratory.	8
6	**Nuclear and Particle physics:** Basic nuclear properties, liquid drop model, nuclear forces, nuclear shell structure, interaction of charged particles and electromagnetic radiation with matter, basic principles of particle detectors, radio-active decays, nuclear reactions, fundamental forces, Gellmann-Nishijima formula Quark model, CPT invariance in different interactions, parity non-conservation in weak interactions.	8
7	**Atoms, Molecules and solids:** Electrons in atoms, exchange symmetry of wavefunctions, atomic and molecular spectra and their explanations including spin-orbit coupling, fine structure, relativistic corrections, spectroscopic terms and selection rules, hyperfine structure, Zeeman, Paschen-Back and Stark effects. Crystal classes and systems, lattice vibration, free electron theory, energy bands in solids, electronic structure of quantum confined structures, impurity levels in doped semiconductor structures. Electron transport, dielectrics, Clausius-Mosstti equation, ferroelectricity, dia-, para, ferro-, antiferro- and ferri-magnetism, superconductivity	12

References:

1) Mathematical Methods for Physicists A comprehensive Guide, George B. Arfken, Hans J. Weber and Frank E. Harris, (Academic Press Elsevier)
2) Classical Mechanics, N. C. Rana and P. S. Joag (Tata McGraw Hill)
3) Introduction to Electrodynamics, David J. Griffiths, (Prentice Press)
4) Quantum Physics, Stephen Gasiorowicz (John Wiley & Sons Inc.)
5) Fundamentals of statistical and thermal physics, Fedrick Reif (McGraw Hill)
6) Concepts of Nuclear Physics, B.L. Choen (Tata McGraw Hill)
7) Quantum Physics, Robert Eisberg and Robert Resnick, (John Wiley and Sons)

Mode of examination

The examination mode is decided by the teachers of this course or research centre will have their own mode of conduction of the examination.

Phy-Ph.D. 003B: Advanced Experimental Physics (04 credits)

Purpose – To train the students for various tools to be used during the course of time.

Need of the course – During the course of research work to execute the objectives of the research problem it is essential to understand the basics of the experimental techniques for proper measurements and analyses.

Structure of the course :– The course consists of four different modules, which covers different aspects of advanced experimental techniques.

Sr. No.	Contents	No of Hours
1	**Module 1: Interaction of radiation and energetic particles with matter** Basic phenomena in case of low energy and high energy interactions (keV and MeV energies) of photons, γ-rays, electrons, protons, neutrons, ions etc. Applications of these processes in synthesis of thin films, coatings, evaporation, sputtering (like plasma, processing, ion-beam processing, LASER processing) and in X-ray photoelectron spectroscopy (XPS).	15
2	**Module 2: Spectroscopic Techniques** Resolution of spectrometer/ instrument (general), Resolving power and influence of different experimental parameters on it. Sensitivity of Measurement. Accuracy of measurements. Instrumental errors and measurement errors. Atomic and molecular spectroscopy UV-vis-NIR absorption spectroscopy, Electronic transition in solids, Transmission reflection and absorption coefficient Infrared spectroscopy, Molecular vibration spectroscopy, Rotational spectroscopy, Bond analysis. Raman spectroscopy. Resonance spectroscopy Angular momentum, Magnetic moments and energy levels, Magnetic resonance, Nuclear Magnetic Resonance, Chemical shifts Fine structure and Intensity variations. Analysis of the spectra.	15
3	**Module 3: Microstructural analysis techniques** Atomic absorption, emission spectroscopy - fundamental of optical atomic spectrometry, Atomic emission spectroscopy. Atomic fluorescence spectrometry. Comparison of Atomic spectroscopies. X-ray diffraction principles, structure factor and diffraction intensity calculations, Rietveld analysis. Scanning electron and Transmission electron microscopy, Field emission microscopy, scanning Tunneling microscopy, Atomic force microscopy.	15

4	**Module 1: Essentials of measurement and analysis** Noise and Signal handling Signal to noise ratio, Johnson Noise and Nyquist theorem, Shot noise, Means of reducing noise. Grounding – shielding, pre-amplifier, Considerations sampling theorem, filters – ADCs/DACs Foamier Transform, Laplace and Fast Fourier Transforms. Data analysis Lorentzian, Gaussian, least square fitting of the spectra. (curve fitting) Deconvolution of spectrum, Derivative peak shapes, Analysis of spectra by taking examples of Raman, X-ray photo-electron, etc. spectra.	15

References:

1. Introduction to analysis and processing of signals, Paul Lynn, Howard W. (Sams and Company, 1983).

2. Probability, Random Variables and Stochastic Process, A. Papoulis, international student Edition (McGraw-Hill International Book Company, 1984)

3. *Vacuum Physics and Techniques,* T. A. Delchar, Chapman and Hall.

4. *Vacuum technology,* A. Roth, (North Holland, Elsevier Science B.V. 1990)

5. *High vacuum techniques,* J. Yarwood, (Chapman and Hall, Londong, 1967)

6. *Nuclear Radiation Detectors,* S.S. Kapoor, V. S. Ramamurthy, (Wiley-Eastern Limited, Bombay)

7. *Experimental Principles and Methods below 1K,* O. U. Lounasmaa, (Academic Press, London and New York, 1974)

8. *Thermometry at ultra-low temperatures,* W. Weyhmann in Methods of Experimental Physics, Vol. II (R. V. Coleman, Academic Press, New York and London, 1974).

9. *Cryophysics,* K. Mendelssohn, Interscience (London, 1960)

10. *Characterization of Materials,* John B. Wachtman & Zwi. H. Kalman, Pub. Butterworth Heinemann (1992)

11 Handbook of Spectroscopy, G. Gauglitz and T. Vo-Dinh (WILEY-VCH Verlag GmbH & Co, 2003)

Mode of examination

The examination mode is decided by the teachers of this course or research centre will have their own mode of conduction of the examination.

Course 4: Phy-Ph.D. 004 - Research & Publication Ethics (2 Credits, 30 Hours)

Purpose: A mandatory UGC course to create awareness about publication ethics, publication misconduct, and best practices in scholarly publishing.

Syllabus Breakdown:

Module	Content	Hours
RPE 01 (Th)	**Philosophy and Ethics:** Definition, nature, scope, and branches of philosophy and ethics.	**4**
RPE 02 (Th)	**Scientific Conduct:** Research integrity, FFP (Fabrication, Falsification, Plagiarism), redundant publications, data misrepresentation.	**4**
RPE 03 (Th)	**Publication Ethics:** COPE guidelines, conflicts of interest, authorship, predatory publishing.	**7**
RPE 04 (Pr)	**Open Access Publishing:** OA initiatives, copyright policies (SHERPA/ROMEO), predatory journal checkers.	**4**
RPE 05 (Pr)	**Publication Misconduct:** Group discussions on ethical case studies; Use of plagiarism software (Turnitin, Urkund).	**4**
RPE 06 (Pr)	**Databases & Research Metrics:** Web of Science, Scopus; Journal Impact Factor, h-index, altmetrics.	**7**

Mode of Examination: The mode of examination shall be decided by the teachers of the course or the respective research centre.

Course 5: Phy-Ph.D. 005 - Pedagogical Training/Industrial Visit (1 Credit, 15 Hours)

Purpose: To develop teaching skills or gain exposure to industrial research and development environments.
Requirement: Students must either undergo pedagogical training or participate in an industrial visit.
Mode of Examination: Evaluation and awarding of credit based on the submission and assessment of a detailed report or an official assessment statement.

4.0 General Information

All rules and regulations regarding the course work shall be adhered to as per SPPU and UGC guidelines.

The course structure is available at: http://sppudocs.unipune.ac.in/sites/circulars/MPhilPhDAdmission%20Circulars/Ph.D.%20Regulations%20SPPU_11072024.pdf

And

http://sppudocs.unipune.ac.in/sites/circulars/MPhilPhDAdmission%20Circulars/195.2025_23.07.25_23072025.pdf

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