Savitribai Phule Pune University

(Formerly University of Pune)

Syllabus for M.Phil./ Ph.D. (PET) Entrance Exam : Physics

Research Methodology

1) **Foundation of Research**: Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory. Characteristics of scientific method - understanding the language of research - Concept, Construct, definition, Variable. Research Process
2) **Problem Identification & Formulation**: definition and formulating the research problem, Necessity of defining the problem, Importance of literature review in defining a problem, Research Question - Investigation Question - Measurement Issues - Hypothesis - Qualities of a good hypothesis - Null hypothesis & Alternative Hypothesis. Hypothesis Testing - Logic & importance
3) **Research Design**: Concept and Importance in Research - Features of a good research design - Exploratory Research Design - Concept, Types and uses, Descriptive Research Design - concept, types and uses. Experimental Design - Concept of Independent & Dependent variables.
4) **Qualitative and Quantitative Research**: Qualitative - Quantitative Research - Concept of measurement, causality, generalization, replication. Merging the two approaches.
5) **Data Collection and analysis**: Execution of the research - Observation and Collection of data - Methods of data collection, hypothesis-testing - Generalization and Interpretation.
6) **Measurement**: Concept of measurement - what is measured? Problem in measurement in research - Validity and Reliability. Levels of measurement - Nominal, Ordinal, Interval, Ratio.
7) **Sampling**: Concept of Statistical population, Sample, Sampling Frame, Sampling Error, Sample size, Non Response. Characteristics of a good sample. Probability Sample - Simple Random Sample, Systematic Sample, Stratified Random Sample & Multi-stage sampling. Determining size of the sample - Practical considerations in sampling and sample size.
8) **Data Analysis**: data Preparation - Univariate analysis (frequency tables, bar charts, pie charts, percentages), Bivariate analysis - Cross tabulations and Chi-square test including testing hypothesis of association.
9) **Interpretation of Data and Paper Writing**: Layout of a Research Paper, Journals in Physics, Impact factor of journals, When and where to publish? Ethical issues related to publishing, Plagiarism and Self-Plagiarism.
10) Use of Encyclopedias, Research Guides, Handbook etc., Academic databases for concerned discipline.
11) **Use of tools / techniques for Research**: methods to search required information effectively, Reference Management Software like Zotero/mendeley, Software for paper formating like LaTeX/MSOffice, software for detection of Plagiarism.

12) **Reporting and Thesis writing:** Structure and components of scientific reports - Types of report - Technical reports and thesis - Significance - Different steps in the preparation - Layout, Structure and Language of typical reports - Illustrations and tables - Bibliography, referencing and footnotes - Oral presentation - Planning - Preparation - Practice - Making presentation - Use of visual aids - Importance of effective communication

13) **Application of results and ethics**: Environmental impacts - Ethical issues - ethical committees - Commercialization - Copy right - royalty - Intellectual property rights and patent law - Trade related aspects of intellectual property Rights - Reproduction of published material - Plagiarism - citation and acknowledgement - citation and acknowledgement - Reproducibility and accountability.
14) **Reasoning and Mentalability**: Analogy, Classification, Series, Coding-Decoding, Direction Sense, Representation Through Venn Diagrams, Mathematical Operations, Arithmetical Reasoning, Inserting the Missing Character, Number, Ranking and Time Sequence Test, Eligibility Test, Representation through Venn-diagrams, Number & symbols ordering, Comprehension questions, Statement & assumptions, Statement & conclusions, Statement & action

Books Recommended

1) Research Methodology - C. R. Kothari
2) Research Methodology : An Introduction - Stuart Melville and Wayne
3) Practical Research Methods - Catherine Dawson
4) Select references from the Internet

REFERENCES

1) Garg, B. L., Karadia, R., Agarwal, F. and Agarwal, U. K., 2002. An introduction to Research Methodology, RBSA Publishers.
2) Kothati , C.R., 1990. Research Methodology: Methods and Techniques. New Age International. 418p.
3) Sinha, S. C. and Dhiman, A. K., 2002. Research Methodology, Ess Ess Publications. 2 columes.
4) Trochim, W. M. K., 2005. Research Methods: the concise knowledge base, Atomic Dog Publishing. 270p
5) Wadehra, B. L. 2000. Law relating to patents, trade marks, copyright designs and geographical indications. Universal Law Publishing.

Additional reading

1) Anthony, M., Graziano, A. M. and Raulin, M. L., 2009. Research Methods: A Process of Inquiry, Allyn and Bacon.
2) Carlos, C. M., 2000. Intellectual property rights, the WTO and developing countries: the TRIPS agreement and policy options. Zed Books, New York.
3) Coley, S. M. and Scheinberg, C. A., 1990, "Proposal Writing", Sage Publications.
4) Day, R. A., 1992. How to Write and Publish a Scientific Paper, Cambridge University Press.
5) Fink, A., 2009. Conducting Research Literature Reviews: From the Internet to Paper. Sage Publications
6) Leedy, P. D. and Ormrod, J. E., 2004 Practical Research: Planning and Design, Prentice Hall.
7) Satarkar, S. V., 2000. Intellectual property rights and Copy right. Ess Ess Publications.

Subject Concerned Syllabus
Physics (Ph.D.)

I. Mathematical Methods of Physics

Elementary probability theory, random variables, binomial, Poisson and normal distributions; Vector algebra and vector calculus; Linear algebra, matrices; Linear differential equations; Special functions ; Fourier series, Fourier and Laplace transforms; Elements of complex analysis: Laurent series-poles, residues and evaluation of integrals; Elementary ideas about tensors; Introductory group theory, SU(2), O(3). Infinite dimensional vector space.

Numerical Methods: roots of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule.

II. Classical Mechanics

Newton's laws; Phase space dynamics; Central-force motion; Collision and scattering; Classical mechanics of system of particles; Rigid body dynamics, moment of inertia tensor, non-inertial frames and pseudoforces; Variational principle, Lagrangian and Hamiltonian formalisms and equations of motion; Poisson brackets and canonical transformations; Symmetry, invariance and conservation laws, cyclic coordinates; Periodic motion, small oscillations and normal modes; Wave equation, phase velocity and group velocity, dispersion; Special theory of relativity, Lorentz transformations, relativistic kinematics and mass–energy equivalence.

III. Electromagnetic Theory

Electrostatics: Gauss' Law and its applications; Laplace and Poisson equations, boundary value problems, multiple expansion; Magnetostatics: Biot-Savart law, Ampere's theorem, electromagnetic induction; Maxwell's equations in free space and linear isotropic media; boundary conditions on fields at interfaces; Scalar and vector potentials; Gauge invariance; Electromagnetic waves in free space, dielectrics, and conductors; Reflection and refraction, polarization, Fresnel's Law, interference, coherence, and diffraction; Transmission lines and wave guides; Dynamics of charged particles in static and uniform electromagnetic fields; Radiation from moving charges, dipoles.

IV. Quantum Mechanics

Wave-particle duality; Wave functions in coordinate and momentum representations; Commutators and Heisenberg's uncertainty principle; Schroedinger equation; Particle moving in a one-dimensional potential; Tunneling through a barrier; Motion in a central potential, symmetry, conservation laws and degeneracy; Orbital angular momentum, Angular momentum algebra, spin; Addition of angular momenta; Dirac's bra and ket notation; Matrix representation; Hydrogen atom, spin-orbit coupling, fine structure; Time-independent perturbation theory (non-degenerate and degnerate) and applications; Variational method; WKB approximation; Time dependent perturbation theory and Fermi's Golden Rule; Selection rules; Semi-classical theory of radiation; Elementary theory of scattering, phase shifts, partial waves, Born approximation; Identical particles, Pauli's exclusion principle, spin-statistics connection; Relativistic quantum mechanics: Klein Gordon and Dirac equations.

V. Thermodynamic and Statistical Physics

Laws of thermodynamics and their consequences; Thermodynamic potentials, Maxwell relations; Chemical potential, phase equilibria; Phase space, micro- and macrostates; Microcanonical, canonical and grand-canonical ensembles and partition functions; Free Energy and connection with thermodynamic quantities; paramagnetism due to localized moments; Thermodynamics of interacting systems, Van der Wall gas, Ising model; Classical and quantum statistics; ideal Bose gases, Bose-Einstein statistics, Principle of detailed balance; Blackbody radiation and Planck's distribution law; Bose-Einstein condensation; Einstein and Debye models for lattice specific heat; ideal Fermi gases, Fermi-Dirac statistics, Free electrons in metal, Fermi energy, Fermi momentum, electron specific heat; Elementary ideas on phase transition, First- and second-order phase transitions.

Random walk and Brownian motion; Introduction to nonequilibrium processes; Diffusion equation.

VI. Electronics

Semiconductor device physics, including diodes, junctions, transistors, field effect devices, homo and heterojunction devices, device structure, device characteristics, frequency dependence and applications; Optoelectronic devices, including solar cells, photodetectors, and LEDs; High-frequency devices, including generators and detectors; Operational amplifiers and their applications; Digital techniques and applications (registers, counters, comparators and similar circuits); A/D and D/A converters; Microprocessor and microcontroller basics.

VII. Experimental Techniques and data analysis

Data interpretation and analysis; Precision and accuracy, error analysis, propagation of errors, least squares fitting, linear and nonlinear curve fitting, chi-square test; Transducers (temperature, pressure/vacuum, magnetic field, vibration, optical, and particle detectors), measurement and control; Signal conditioning and recovery, impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding; Fourier transforms; lock-in detector, box-car integrator, modulation techniques.

Applications of the above experimental and analytical techniques to typical undergraduate and graduate level laboratory experiments.

VIII. Atomic & Molecular Physics

Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen atom; and alkali atoms Relativistic corrections for energy levels of hydrogen; Hyperfine structure, selection rules; width of spectral lines; LS & JJ coupling, Hund's rule; Mechanism of line broadening, Zeeman, Paschen Back & Stark effect; X-ray spectroscopy; Principle of resonance spectroscopy, Electron spin resonance, Nuclear magnetic resonance, chemical shift; Molecular physics, rotational, vibrational, electronic, and Raman spectra of diatomic molecules, symmetry groups of molecules, point groups and classification of molecules; Frank – Condon principle and selection rules; Spontaneous and stimulated emission, Einstein A & B coefficients; Lasers, optical pumping, population inversion, rate equation, He-Ne lasers; Modes of resonators and coherence length.

IX. Condensed Matter Physics

Bravais lattices; Reciprocal lattice, diffraction and the structure factor; Defects and dislocations; Ordered phases of matter, translational and orientational order, kinds of liquid crystalline order, Quasicrystals and glasses. Bonding of solids; Elastic properties, phonons, lattice specific heat; Free electron theory, electronic specific heat, Pauli paramagnetic susceptibility; Response and relaxation phenomena; Drude model; Hall effect and thermoelectric power; Electron motion in a periodic potential, band theory of metals, insulators and semiconductors, tight- binding approximation, impurity levels in doped semiconductors; Diamagnetism, paramagnetism, and ferromagnetism; Superconductivity, Meissner effect, type – I and type - II superconductors, London theory of superconductivity, Josephson junctions.

X. Nuclear and Particle Physics

Basic nuclear properties: size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Liquid drop model; Nuclear stability, radioactive decay, fission and fusion; Nature of the nuclear force, form of nucleon-nucleon potential; Charge-independence and charge-symmetry of nuclear forces; Isospin; Deuteron problem; Low energy N-N scattering; Evidence of shell structure, single- particle shell model, its validity and limitations; Rotational spectra; Elementary ideas of alpha, beta and gamma decays and their selection rules; Nuclear reactions, reaction mechanisms, compound nuclei and direct reactions; Classification of fundamental forces; Elementary particles (quarks, baryons, mesons, leptons); Spin and parity assignments, isospin, strangeness; Gell-Mann-Nishijima formula; C, P, and T invariance and applications of symmetry arguments to particle reactions, parity non-conservation in weak interaction.

Subject Concerned Syllabus
Physics (M.Phil)

- Quantum Mechanics: Schrödinger equation, Particle in potential wells, harmonic oscillator, hydrogen atom. Operators and state vectors, Perturbation theory, Interaction of radiation with matter, Scattering theory, Born approximation, Scattering by a rigid sphere and square-well potential.
- Mathematical Methods: Vectors and operators, Hermitian and unitary operators, Analytical functions, residues, contour integration, Special Functions, Differential equations and series solutions, Probability, Binomial, Poisson and Gaussian distributions, Random walks.
- Classical Mechanics: Lagrangian and Hamiltonian formalisms, symmetries and conservation laws, motion in the central force fields, collision and scattering, rigid body dynamics. Small oscillation and normal modes.
- Electrodynamics: Laplace and Poisson equations, boundary value problem, multipole expansions, dielectrics, Ampere's theorem, Biot-Savart law, electromagnetic induction, Maxwell's equation in free space, Scalar and vector potentials, Gauge invariance, E.M. waves, reflection, refraction, dispersion, Diffraction and polarization. Motion of a charged particle in electric and magnetic fields, Radiation from moving charges, Radiation from a dipole.

- Electronics: Physics of p-n junction, diode characteristics, BJT, UJT, FET, JEET, MOSFET transistors solar cell, photodiodes, LED, phototransistors, AC and DC amplifiers, RC coupled amplifiers, feedback in amplifiers and oscillators, OP-amp and its applications, integrator, differentiator, comparator, Schmitt trigger, active filters, NAND, NOR, XOR, gates, llip-flops, shift registers, counters, A/D and D/A converter.
- Atomic and Molecular Physics: Quantum state of an electron in an atom, hydrogen atom spectrum, electron spin, spectroscopic terms & selection rules, hyperfine structure, periodic table, LS & JJ coupling, Hund's rule. Line Broadening, Zeeman & Stark effects, Molecular Structure and Molecular Spectra, Electronic structure of polyatomic molecules: hybrid orbitals, bonding in hydrocarbons, Rotational levels in diatomic and polyatomic molecules.
- Nuclear Physics: Basic properties of nucleus –charge, spin, parity, iso-spin etc., Nuclear binding energy, Nuclear decay and nuclear interactions, Nuclear models – shell model, liquid drop model, Nuclear reactors and accelerators, Radiation detectors, Elementary particles. Standard model.
- Solid State Physics: Crystal structure, Real and Reciprocal lattice – Brillouin zones, Lattice dynamics and phonons, Electronic band structure, Bloch theorem, Nearly free electron model, Band structure calculation methods, Electrical properties of semiconductors, Dielectric and optical properties of solids, Magnetism in solids - diamagnetism , paramagnetism, and ferromagnetism, Magnetic domains, Superconductivity – Type-I and Type-II superconductors, Meissner effect, isotope effect, energy gap, Josephson junction.
- Statistical Mechanics: Review of thermodynamics – laws of thermodynamics, free energies. Phase space formulation of statistical mechanics, Microstates and macrostates, Microcanonical, canonical, grand-canonical ensembles, Quantum statistics, Density operator, Maxwell-Boltzmann, Fermi-Dirac and Bose-Einestein statistics, Ideal Fermi gas and ideal Bose gas, Bose-Einstein condensation.