Syllabus for Ph.D. Coursework
Physics Department
Cotton University
2018

Ph.D. students of Physics at Cotton University are required to complete a course work of 14 credits, spread over 4 courses, in the first semester of Ph.D. Programme. Courses of 4 and 2 credits will be in the L+T+P format. For the purpose of computation of workload the mechanism is

1 credit = 1 theory period of 1 hour duration per week
1 credit = 1 tutorial period of 1 hour duration per week
1 credit = 1 practical period of 2 hour duration per week

Courses:

1. **Research Methodology:** Common course for the Department of Physics, Chemistry, Mathematics, Computer Science & IT and Statistics (**Compulsory**)
2. **Core Course:** Common course for all branches of Physics Department (**Compulsory**)
3. **Special Paper:** Only one optional paper shall be opted which is related to the topic of his research from the given several optional papers and is considered as his/her "**Special Paper".**
4. **Research and Publication Ethics: Common Course** and c**ompulsory for all faculties).**

Paper-wise Credit distribution:

Paper Code	Paper Title	Credit L+T+P	Marks
PCM2500RM	Research Methodology (Compulsory Paper)	3+0+1= 4	7 0+30=100
PHY2501CC	Core Course: **General Physics and Experimental Techniques** (Compulsory Paper)	3+1+0 =4	100
PHY2502SP1	**Advanced Astronomy and Astrophysics:** Special Paper (Optional):	3+1+0 =4	100
PHY2502SP2	**Advanced Computing:** Special Paper (Optional)	3+1+0 =4	100
PHY2502SP3	**Gravitational Wave Science:** Special Paper (Optional):	3+1+0 =4	100
PHY2502SP4	**High Energy Physics:** Special Paper (Optional)	3+1+0 =4	100
PHY2502SP5	**Nonlinear Optics and Applications:** Special Paper (Optional)	3+1+0 =4	100
PHY2502SP6	**Material Sciences:** Special Paper (Optional)	3+1+0 =4	100
PHY2502SP7	**Nanomaterials for Optoelectronics:** Special Paper (Optional):	3+1+0 =4	100
PHY2502SP8	**Plasma Processing:** Special Paper (Optional)	3+1+0 =4	100
PHY2502SP9	**Radiation Physics:** Special Paper (Optional)	3+1+0 =4	100
PHY2502SP10	**Radon: Exposure Risks and Measurements:** Special Paper (Optional):	3+1+0 =4	100
PHY2502SP11	**Accretion Physics and Radiative: Processes** Special Paper (Optional)	3+1+0 =4	100
PHY2502SP12	**General Circulation and Climate (Atmospheric Physics)** Special Paper (Optional)	3+1+0 =4	100
RPE2503GP	**Research and Publication Ethics (RPE)**	2+0+0=2	50

1. Research Methodology: Compulsory paper (Paper Code: *PCM2500RM*), (Credit, 3+0+1=4)

[For the Departments of Physics, Chemistry, Mathematics, Computer Sciences &IT and Statistics]

Unit 1: Introduction to Research Methodology

Meaning and objectives of research, Types of Research, Qualitative and Quantitative approaches of research, Criteria of good research, Research problem, Importance of defining the research problem, Techniques involved in defining a research problem, Illustration of research problem, Characteristics of Scientific method, Research Process, Literature survey

Unit 2: Hypothesis and research methodology

Research Design: Meaning, Importance of designing of research, Features of a good research design, Design of Exploratory Research and Descriptive Research

Experimental Design: Concept of Independent & Dependent variables. Concept of Hypotheses, Characteristics of Hypothesis, Null hypothesis & Alternative Hypothesis

Hypothesis Testing –Logic & Importance

Unit 3: Data collection and analysis

Observation and collection of data- primary and secondary data, Methods of collection of data- Sampling methods, Data processing and analysing strategies, Data analysis with statistical methods, Hypothesis testing, Generalization and Interpretations

Unit 4: Scientific paper writing

Research communication and publication, when and where to publish, Layout of a research paper, Journal impact factor and citation, Scientific Citation Index and Extended List, H-index and i-10 index

Unit 5: Ethics in Research, Copyright and Intellectual Property Rights

Brief introduction to ethics and etiquettes in research with reference to honesty in scientific communication, reporting data, fabricating, falsifying and misinterpreting data

Plagiarism: Definition, various forms of plagiarism, self plagiarism, software for checking plagiarism

Intellectual property rights: Intellectual property and intellectual property rights, patent, trade mark, industrial design, geographical indication, copyright laws, world intellectual property organization.

Reference

1. *Research Methodology-Methods and Techniques 2/e by C. K. Kothari, New Age International, New Delhi, 2004.*
2. *Research Methodology: A Step by Step Guide for Beginners 2/e by R. Kumar, Pearson India, 2005.*

3. *Statistics By T. R. Jain & S. C. Aggarwal, VK Enterprises, India.*
4. *The Researcher's Bible by A. Bundy, B. D. Boulay, J. Howe and G. Plotkin, University of Edinburgh, 1995*
5. *Reports and mannuals available in the official website of IPO (www.ip india .nic.in/) and WIPO (www. wipo .int/).*

[**For Credit 1: The students have to prepare a report of literature survey (up to 3000 words) on a research topic assigned to him/her and submit the same to the concerned department before 2 (two) weeks of the final Course Work Examinations. This credit is in lieu practical (P) as stated in the L+T+P credit format**]

2. Core Course: General Physics and Experimental Techniques (Compulsory paper) Paper Code: *PHY2501CC* (Credit, 3+1+0=4)

Unit 1: General Physics:

Matrix: Eigenvalues and eigenvectors, square root of a matrix; Lorentz transformations in fully relativistic notations, Structure of the Minkowskispacetime, worldline of a point particle and its equation of motion; covariant formulation of electrodynamics and gauge transformation, classical fields and Euler-Lagrangian equation for fields; salient features of Bose-Einstein statistics and Fermi-Dirac statistics and their applications. Angular Momentum Formalism: Hydrogen atom problem in spherical coordinates, Angular momentum, addition of angular momentum, Clebsch–Gordon coefficients, Relativistic quantum mechanics, Covariant form of Dirac equation, Dirac gammamatrices and their properties. Many body problem in Quantum mechanics: Quasiparticles and collective excitation, Spin wave function and exchange interactions and Heisenberg Dirac Hamiltonian.

Unit 2: Experimental Techniques: Production and measurements of Low pressure: Rotary, absorption, oil diffusion, Gauges, Pirani, Penning, leak detection; principles and characteristics of LASERS, principle and applications of powder X-ray diffractometer, spectrometer (IR and UV–visible), Fourier transforminfrared (FTIR) spectrometer SEM,TEM, atomic force microscope, PIXE (Proton induced X-Ray emission), particle detector and data analysis, wave synthesis and analysis, analog and digital computation.

3. Special Papers: *(Only one choice and there is provision to add more optional papers if manpower is available)*

3.1: Advanced Astronomy and Astrophysics (*PHY2502SP1*), Credit = 4 (3+1+0)

Unit 1: Observational Tools and Techniques

Telescopes: Types of Telescopes, Design and Construction of a Simple Optical Telescope, SchmidtTelescope, Solar Telescope.

Detectors: Detectors for Optical and Infrared regions, Astronomical CCD's Photometry and Spectroscopy: Simple design of an Astronomical Photometer, Design of a Simple Spectrograph

Celestial Coordinates: Types and their Description, Concept of Time, Scheduling an Observational Time, Query Using Astronomical Databases, Finding Charts.

Unit 2:Stellar Structure and Evolution

Stellar Spectra: Origin and Formation of Spectral lines, HR diagram, Equations of Stellar Structure, Polytropes: Lane Emden Equation and its Solution, Energy Generation in Stars: Calculation of Thermonuclear Reaction Rates for Non-resonant and beta-decay Reactions; The Various Reaction Chains: pp-I,II,III, CNO, He-burning, C-burning, Si-burning, Photo-dissociation, Stellar Models, Nuclear Astrophysics: Supernovae, White dwarfs, Neutron stars and Black holes.

Unit 3: Variable Star Astronomy

Light Curves of Variable Stars: Importance and Classification of Variable Stars, Cause of Variability, Instability Strip in the HR Diagram, Detection of Variability from huge Astronomical Databases, Astronomical Photometry of Variable Stars: Absolute and Differential Photometry, Distance Determination in Astronomy: Standard Candles such as RR Lyraes, Cepheids, etc, Wesenheit Index: Extragalatic Distance Determination, Numerical Modeling of Pulations

Fourier Decomposition Method: Connection between the Light Curve Structure and Physical Parameters of Stars, Principal Component Analysis of the Light Curves of Variable Stars

Modeling of Light Curves of Binary Stars, Physical Parameters and Distance Determination from the combined Photometry and Spectroscopy of Binary Stars

Unit 4: Period Determination Techniques in Astronomy

Period Finding Techniques: Fast Fourier Transform, Discrete Fourier Transform, Lomb-ScarglePeriodograms, Phase Dispersion Minimization, String Length Method, Maximum Entropy Method, Analysis of Variance, etc.

Unit 5:Numerical and Statistical Techniques

Numerical Techniques in Astronomy and Astrophysics: Numerical Integration and Interpolation, Curve Fitting, Numerical Solutions of Algebraic, Ordinary Differential and Partial Differential Equations. Random Number Generation, Statistical Techniques: Probability, Discrete and Continuous Random Variables, Central Limit Theorem. Hypothesis Testing, Sampling Methods, Multivariate Analysis, Regression, Time Series Analysis, Fourier Transforms. Data Reduction and Error Analysis Techniques, Comparing Data with a model, Method of Maximum Likelihood Estimation: Gaussian Data and Poissonian Data.

(Any one of the high-level programming languages/softwares can be used in the problem solving using the computer)

References:

1. *Bevington, Data Reduction and Error Analysis for Physical Sciences, McGraw-Hill,*

2003.

2. *Babu G. J. &Fiegelson, E. D., Astrostatistics, Chapman and Hall, 1996.*
3. *Hoel, P. G. , Port, S. C., & Stone, C. J., Introduction to probability and Introduction to statistical theory, Houghton & Mifflin, 1971.*
4. *Press, W.H., et al.: Numerical Recipes, Press, 1992.*
5. *Clayton, D.D.: Principles of Stellar Evolution and Nucleosynthesis.*
6. *Shapiro, S., and Teukolsky, S.: Black Holes,White Dwarfs and Neutron Stars.*
7. *Longair, M.S.: High Energy Astrophysics.*
8. *Chandrashekar, S.: Introduction to the study of Stellar Structure*
9. *Clayton, D. D.: Principles of Stellar Evolution and Nucloesynthesis*
10. *Henden, Arne A. &Kaitchuk, Ronald H.: Astronomical Photometry, Willmann-Bell, Inc., 1990.*
11. *Bradley W. Carroll, Dale A. Ostlie: Introduction to Modern Astrophysics, Second Edition, PEARSON: Addison Wesley, 2007*

3.2: Advanced Computing (*PHY2502SP2*), Credit = 4 (3+1+0)

Unit 1: Statistical Data Analysis

Measuring errors: Accuracy and Precision, Systematic and Random Errors, Significant Figures and Roundoff, Propagation of Errors, Analyzing and Reducing Uncertainties: Parent and Sample Distributions, Mean, Median, Mode, the Probability Function: Continuous and Discrete Distributions, the Maximum Likelihood (ML) Method of parameter estimation and Estimations of Errors on the ML estimators.

Statistical Interpretation of Data: Moments of a Distribution, hyptheses Testing: Student's t-test, F-test, Chi-Square test, Kolmogorov-Smirnov Test, Measures of Association Based on Entropy, t-test and F-test in Linear and Non-Linear RegressionalAnalsysis

Machine Learning: Neural Networks, Support Vector Machines, Multivariate Analysis: Principal Component Analysis, Linear Dscriminant Analysis and Reconstruction Algorithms, Statistical Data Analysis using R Statistical Package, Numerical Methods using Python Programming

Unit 2: Simulation and Monte Carlo Methods

Monte Carlo Methods: Meaning, History and Origin, Buffon's needle problem, Various methods for generation of pseudo-random numbers: Linear congruential generators, Multiple recursive generators, Transformation Method, Acceptance-Rejection Method, Monte Carlo evaluation of pi, Simulation of simple processes: coin tossing or dice throwing game, Area under the curves using Monte Carlo, Volume of a complicated 3D region by Monte Carlo, Calculation of integrals: Proper, Improper and Multidimensional Integrals, Crude Sampling and Importance Sampling, Metropolis Algorithm, Variational Monte Carlo Techniques:

Applications on Simple Quantum Mechanical Systems such as simple harmonic oscillators, particle in a box and hydrogen atom.

Unit 3: Fast Fourier Transform

Fourier Transform of discretely sampled data, Fast Fourier Transform (FFT), FFT of Real Functions, Sine and Cosine Transforms.

Unit 4: Fourier and Spectral Applications

Convolution and deconvolution using FFT, Correlation and Autocorrelation using FFT, Optimal (Wiener) Filtering using the FFT, Power Spectrum Estimation using the FFT, Spectral Analysis of Unevenly Sampled Data: Lomb-Scargle Method, Analysis of a time series and search for periodicity.

References:

1. *Data Reduction and Error Analysis for the Physical Sciences, Third Edition, Philip R. Bevington and D. Keith Robinson, McGraw-Hill, New York, 2003.*
2. *Statistical Data Analysis, G. Cowan, Oxford University Press, 1997.*
3. *Simulation: Statistical Modeling and Decision Science Series, S. M. Ross, Academic Press, 2006.*
4. *Numerical Recipes in Fortran (The Art of Scientific Computing), Second Edition, William H. Press, Saul A. Teukolsky, William T. Vettering, Brian P. Flannery, Cambridge University Press, 1996*
5. *Introductory Methods of Numerical Analysis. S. S. Sastry, Prentice-Hall of India Private Limited, 2005*
6. *Numerical Methods in Engineering with Python, JaanKiusalaas, Cambridge University Press, 2010*
7. *The R Book, Michael J Crawley, John Wiley & Sons Ltd, West Sussex, England, 2007*
8. *Python Machine Learning, Sebastian Raschka, Packt Publishing, 2015*

3.3: Gravitational Wave Science (*PHY2502SP3*), Credit = 4 (3+1+0)

Unit 1: Introduction

Gravitational wave: a new window of the Universe, Its importance in Physics, Astrophysics and Cosmology.

Unit 2: Fundamentals of Gravitational Wave

Introduction to tensor and General relativity, Einstein Field equation, Linearized field equations, Wave equation,Transverse-traceless gauge and polarisation

Unit 3: Effect of Gravitational Wave

Geodesic motion, Geodesic deviaion,Effect of gravitational wave on two freely falling particles Effect of gravitational waves in ring of particles

Unit 4: Generation of Gravitational Waves

Power per solid angle, Energy per solid angle emitted in terms of Fourier integral of the source, Emission of Gravitational radiation in collision, Gravitational Radiation from sun, Sources in slow motion and weak field, Quadrapole formula of emitted energy, momentum and angular momentum

Unit 5: Sources of Gravitational Wave

Binary system, rotating neutron star, Taylor pulser, Cosmological source, binaryinspiral, post newtonian correction

Unit 6: Detection of Gravitational Wave

Weber bar detectors, Laser Interferometric detector and their response

References:

1. *B. Schutz. A first course in general relativity. Cambridge university press, 2009*
2. *Weinberg Steven, "Gravitation and Cosmology: Principles and Applications of General Theory of Relativity"*
3. *C. Misner, K. Thorne, and J. Wheeler. Gravitation, WH Freeman & Co., 1973*
4. *J. D. Creighton and W. G. Anderson, Gravitational-wave physics and astronomy: an introduction to theory, experiment and data analysis, John Wiley & Sons, 2012*
5. *M. Maggiore, Gravitational waves, Oxford University Press, 2007*
6. *B. Sathyaprakash and B. F. Schutz, "Physics, Astrophysics and Cosmology with Gravitational Waves", Living Reviews in Relativity 12.2, 2009*

3.4 High Energy Physics (*PHY2502SP4*), Credit = 4 (3+1+0)

Unit 1: Electrodynamics of Quarks and Hadrons [8 lectures]:

Deep-Inelastic Scattering (DIS) and structure function, Parton model, Bjorken scaling and its violation and QCD evolution equations

Unit 2: Gauge theories [10 lectures]:

Gauge theory of fundamental interactions– global and local gauge transformations.

Abelian U(1) (QED) and non-Abelian (Yang-Mills) groups- SU(2) (isospin), SU(3)C and (QCD)

Unit 3: Spontaneous Symmetry Breaking (SSB) [12 lectures]:

Spontaneous Symmetry Breaking: Local and Global symmtery breaking, Goldstone boson, Higgs mechanism. Standard model of electroweak unification, gauge bosons, and Beyond Standard Model- Grand Unified Theories (GUTs) – SU(5) and SO(10), Minimal Supersymmetric Standard Model (MSSM).

Unit 4: Neutrino Physics [12 lectures]:

Solar and atmospheric neutrino puzzles, neutrino oscillation (vacuum, MSW mechanism), neutrino masses, mixing angles, past and recent neutrino oscillation experiments and their results, seesaw mechanisms (type-I, type-II and inverse seesaw mechanisms).

Recommended books:

1. Quarks and leptons: An introductory Course in Modern Particle Physics – Francis Halzen and Alan D. Martin.

2. Introduction to Elementary Particles - David Griffiths.

3. Gauge Theory of elementary particle physics - Ta-Pei Cheng and Ling-Fong Li.

4. Massive Neutrinos in Physics and Astrophysics - R N Mohapatra and P B Pal.

3.5: Nonlinear Optics and Applications (*PHY2502SP5*), Credit = 4 (3+1+0)

Unit 1: Introduction & Linear Optics:

EM Wave equation (Homogeneous and Isotropic medium), Plane wave solution, Intensity and Amplitude relation, Linear Polarization, Classical 1D anharmonic oscillator , Refractive Index, Dispersion (Damped Harmonic Oscillator Model, Sellmeier Equation). Polarization Tensor, Susceptibility Tensor , Wave motion in Crystal, E-Ray & O-Ray, Walk Off.

Unit 2: Nonlinear Optics:

Nonlinear Susceptibility, 2nd order nonlinear effect (χ (2) $\neq$ 0), 2nd harmonic generation, Nonlinear Maxwell's equation, Concept of phase matching,

3rd order nonlinear effect (χ (3) $\neq$ 0), Optical Kerr effect, Self Phase Modulation (SPM), 3rd harmonic generation, Two wave interaction, Cross Phase Modulation (XPM).

Stimulated Raman Scattering, Raman Gain, Applications.

Unit 3: Parametric Processes:

Three wave interaction, Difference frequency generation, Manley-Rowe Relation,

Nonlinear absorption / Two Photon Absorption (TPA), Four Wave mixing, Cross Talk, Optical Phase Conjugation, Supercontinuum generations

Unit 4:Optical soliton:

Nonlinear Schrödinger Equation**:** Spatial soliton, Temporal soliton, spatio-temporal soliton, soliton interactions, Applications of optical solitons

Modulation Instability, Perturbation of solitons, Soliton stability

Book:

1. Nonlinear Optics by R. W. Boyd (3 Ed), Elsevier 2008

2. Introducction to nonkerr law optical solitons by A Biswas, S Konar, Chapman & Hall/CRC Applied Mathematics & Nonlinear Science; 2006.

3.6 Paper Name: Material Sciences (Paper Code: *PHY2502SP6)*

Unit 1: Preparation, Synthesis of materials and growth of thin films (Physical and chemical)

(a) Methods of crystal growth: Solution methods, Melt methods, Homogeneous nucleation and heterogeneous nucleation, Energy of formation of a nucleus

(b) Preparation of Amorphous Materials: Introduction to amorphous materials & conducting mechanism, Melt Quenching technique, Thermal Evaporation method, Ball milling, Electrodeposition, Sputtering, Glow-discharge decomposition. Shear amorphization.

(c) Thin film and epitaxial growth: Thermal Evaporation method, Sputtering, CVD, LPCVD, Spin Coating, Molecular beam epitaxy

(d) Ceramic material preparation: Introduction to ceramic materials, properties, preparation; Recrystalization and Grain Growth, solid state sintering, sintering with reactive liquid, pressure sintering.Synthesis of Nano-Scale ceramics powder

(e) Preparation of Nanomaterials:

(f) Sol gel technique, Chemical Vapor Deposition, plasma arc discharge, sputtering, evaporation, Pulsed laser deposition and electro-deposition

(g) Preparation of Conducting Polymers: Conducting polymer, Properties, Conduction mechanism, Preparation; Chemical Oxidation polymerization, Plasma polymerisation

Unit 2: Characterization of thin films:

(a) XRD: X-ray methods for orienting crystals, applications of XRD, Diffraction from regular and faulted closed packed structures, Broadening of diffraction spots due to defects, Line profile analysis, crystal structure analysis, measurement of intensities of X- ray reflection

(b) Surface structure and topography – SEM, TEM, XRF, EDXRF, STM, LEED, AFM

(c) Microstructure – UVVIS, Raman, FTIR, Optical microscopy, small angle scattering

(d) Phase changes, crystalline and amorphous fractions – DSC

(e) Thermo-gravimetric methods – TGA and DTA

(f) Mechanical properties: Elastic properties, strength measurements in bulk and thin films, nano-indentation, Physics of fracture – Griffith's theory of brittle fracture, ductile fracture, length scale issues and size effects (5)

Unit 3: Properties (Electrical and Optical) of semiconducting thin films and junctions

Unit 4: Photovoltaic effect in semiconducting thin films junctions

Unit 5: Sensor: (a) Sensing materials and properties, (b) High energy Radiation (X-ray and UV) Sensing properties of materials

Unit 6: Luminescence properties of materials

Unit 7: Physics of Semiconductor Structures and Quantum Well Devices: Structure and Principle of Operation of (i) High Electron Mobility Transistor, (ii) Resonant Tunneling Diode (iii) Quantum Well Laser (iv) Quantum Well Detector

Unit 8: Problem Solving

References:

1. *Experimental Techniques of Surface Science, Woodruff and Delchar*
2. *Solid State Physics, Ashcroft and Mermin*
3. *Amorphous Materials, S. R. Elliot*
4. *Fundamentals of Surfaces and Thin Films, L. C. Feldman and J.W. Mayer Analysis*
5. *An Introduction of X-ray Crystallography, M.M. Woolfson*
6. *Elements of X-Ray Diffraction,Cullity B D, Addision-Westly Publishing Company, Inc., 2nd Edition, (1978)*
7. *Essentials of Crystallography, M. A. Wahab, Narosa, New Delhi*
8. *Metal-semiconductor Contacts,Roderich E H,, Clarendon Press, Oxford*
9. *Sze S M, Physics of Semiconductor Devices, 2nd edition, (Wiley Eastern limited, New Delhi, reprint, 1983)*
10. *Chopra K L, Thin Film Technology and Application, Chopra K L and Malhotra, L K (Eds.), Tata McGraw Hill Publishing Co., New Delhi, (1984)*
11. *Pankove J I, Optical Processes in Semiconductors, Dover Publications, Inc, New York, (1971)*
12. *Sharma B L and Purohit R K, Semiconductor Heterojunctions, Pergamon*
13. *Mitchell K W, Physics of Solar Cell, edited by Jain S C, Radhakrishna S and ReddyT R S*
14. *Jain V K, Physics of Solar Cells, edited by Jain S C, Radhakrishna S and T R S Reddy, First edition (1984)*
15. *Mitchell K W, Physics of Solar Cells, edited by Join S C, Radhakrishna S and*

*Reddy T R S, International Council of Scientific Unions, Madras (India), First edition**159:** (1984)*

16. *Singh S N, Das B K, Narula R C and Jain S C, Photovoltaic Materials and Devices, (eds.) Das B K and Singh S N, (Wiley Eastern Limited, New Delhi, (1984), 117*
17. *Introduction to Ceramics, 2nd Ed. W. D. Kingery, H. K. Bowen and D. R. UhlmannJohnWiley& Sons, Singapore, 1991*
18. *Ceramic Processing, M. N. Rahaman, CRC Press, 2007.*
19. *Introduction to the Principles of Ceramic Processing, J. S. Reed 2nd Ed., John Wiley & Sons, 1995*
20. *Non-Crystalline Semiconductors, Device and Mott.*
21. *Amorphous Semiconductors , Richard and Zallen*
22. *Handbook of Conducting Polymers, T.A Skotheim and J.R. Reynolds*
23. *Nanomaterials: Synthesis; properties and applications, A.S. Edelstein and R.C.*

Commarata

3.7Nanomaterials for Optoelectronics (*PHY2502SP7*), Credit = 4 (3+1+0)

Unit 1: Introduction: Fundamentals of nanoscience and nanotechnology

Unit 2: Physics of Nanostructures

Size effects: quantum well, quantum dot, quantum wire - specific features of nanoscale growth: fundamentals of nucleation and growth - nanoscale properties: optical, electrical, thermal and mechanical

Unit 3: Preparation of Nanostructured Materials

Materials: 0D/1D/2D structures, metallic, semiconducting, oxide and nitride materials, carbon nano-allotropes (graphene, carbon nanotube/fiber), nanocomposites (organic, inorganic and hybrid)

Processing techniques: Solution growth techniques (chemical, electrochemical, sol-gel etc.) - Gas phase techniques (ALD, CVD, PVD, sputtering, PECVD etc.) - Evaporation

Unit 4:Nanostructures for Optoelectronics

Excitonic and plasmonic light harvesting devices - various device configurations and fabrication strategies - Device physics of excitonic and nano-plasmonic devices: light absorption, carrier generation, carrier injection and transport mechanism

Unit 5:Characterization of Nanomaterials/Devices

Fundamentals of experimental techniques - approaches and data interpretation - Analytical tools (FTIR, UV-Vis, PL, XRD, SEM, TEM, AFM, XPS, Raman) - Time resolved measurements, Electrical Characterization of materials and devices

References:

1. *Nanophysics and Nanotechnology, E. L. Wolf, 2006, Wiley-VCH*
2. *Principles of Nano-optics, L. Novotny and B. Hecht, 2006, Cambridge University Press*
3. *Modern Introduction to Surface Plasmons, D. Sarid and W. Challener, 2010, Cambridge University Press*
4. *Physics of Optoelectronic Devices, S. L. Chuang, 1995, Wiley-Interscience*
5. *Organic Photovoltaics: Materials, Device Physics and Manufacturing Technologies Ed. C. Brabec, V. Dyakonov, U. Scherf, 2012, Wiley-VCH*
6. *Semiconductor Optoelectronic Devices: Introduction to Physics and Simulation J. Piprek, 2013, Academic Press*

3.8: Plasma Processing(*PHY2502SP8*), Credit = 4 (3+1+0)

Unit 1: Introduction

Definition - Physics of plasmas - Concept of Temperature - Thermal plasma - Cold plasma - Debye shielding - Plasma parameters - Sheath - Bohm sheath criterion.

Unit 2: Different Types of Plasma and Laboratory Production

Gas discharge processes (dc, rf, pulsed dc) - Atmospheric discharges - Capacitive and inductively coupled plasma - Magnetron plasma, - Hybrid plasma - Plasma reactor - Vacuum system - Pressure gauges - Gas/Precursor flow controllers.

Unit 3:Plasma Chemistry

Chemical reactions - Molecular Collisions - Surface processes - PECVD - Plasma polymerization - Fundamentals of radical/ion assisted plasma chemistry - Deposition - Hybrid plasma processing.

Unit 4:Plasma Etching

Ion etching- Reactive ion etching - Plasma ashing - Plasma based pattern transfer.

Unit 5: Plasma Diagnostics

Langmuir probe - Emissive probe - Electron energy distribution function - Optical emission spectroscopy - Actinometry – Mass spectrometry.

References:

1. *Introduction to Plasma Physics, F. F. Chen, 2012, Springer*
2. *Fundamentals of Plasma Physics, J. A. Bittencourt, 2004, Springer*
3. *Cold Plasma in Materials Fabrication: From Fundamentals to Applications, A. Grill, 1994, Wiley-IEEE Press*
4. *Industrial Plasma Engineering (Vol. I): Principles, J. R. Roth, 2001, CRC Press*
5. *Industrial Plasma Engineering (Vol. II): Applications to Nonthermal Plasma Processing, J. R. Roth, 2001, CRC Press*
6. *Glow Discharge Processes: Sputtering and Plasma Etching, B. Chapman, 1980, Wiley-Blackwell*

3.9: Radiation Physics(*PHY2502SP9*), Credit = 4 (3+1+0)

Unit 1: Basics of Nuclear Physics

Nuclear forces and nuclear structure, Isotopes of elements, Excitation and Ionisation, Nuclear stability and neutron proton ratio, Mass defect, Binding energy, Packing fraction.

Nuclear Reactions: Different nuclear reactions, nuclear fission, nuclear fusion, nuclear cross-section

Unit 2: Radioactivity

Natural radioactivity: Unstable nuclei, radionulcides, radioactive law, mean life, half-life, activity of a radioactive element, determination of decay constant and half-life, statistical nature of radioactivity, radioactive branching, radioactive decay series, law of successive disintegration and radioactive equilibrium,

Artificial radioactivity: The artificial radionuclides, the transuranic elements, alpha-emitters, isotope tables and nuclide charts.

Units of radioactivity, Applications of radioactivity

Unit 3: Interaction of radiation with matter

Charged particle radiations: General aspects, stopping power range, energy deposition, uncharged particle radiations

Unit 4: Radiation Dosimetry

Units of radiation dose, Biological effects of radiation: Interaction with the cells and somatic effects of radiation.

Radiation protection standards: Radiation dose to individuals from natural radioactivity, basic concepts of radiation protection standards, Radiation accidents

Unit 5: Sources of Radiations

Natural radiations: Terrestrial radionuclides (^{235}U, ^{238}U, ^{232}Th, ^{40}K), important radionulcides in^{238}U and ^{232}Th decay chains, NORM, Cosmic radiations.

Man-made radiations: Radioactive sources, nuclear reactors.

Radiation generators: Charged particle productions- Linear accelerator, betatron, cyclotron, X-ray productions, Neutron productions-(d,n) reaction and (p,n) reaction, neutron production for neutron therapy

Applications of ionising radiations in medicine, industry and agriculture

Unit 6: Radiation Detection and Measurements

Principles of radiation detection, Ionisation chambers, Geiger-Muller counter, Spark chamber, Scintillation counters, Cherenkov counter, Nuclear emulsion technique, TLD, Solid state nuclear track detectors (SSNTD), Gamma ray spectrometers, Nuclear electronics.

Uncertainty principles: Poisson and Normal distribution, statistical errors

References:

1. *J. E. Turner: Atoms, Radiation and Radiation Protection, 2nd Edition, Willey Interscience.*
2. *F. H. Attix: Introduction to Radiological Physics and Radiation Dosimetry, Willey Interscience.*
3. *I. Kaplan: Nuclear Physics, Oxford & IBH Publishing Pvt. Ltd.*
4. *K. S. Krane: Introductory Nuclear Physics, Willey, New York.*
5. *J. W. Price: Nuclear Radiation Detectors, McGraw Hill, New York.*
6. *W. R. Leo: Techniques for Nuclear and Particle Physics Experiments, Springer-Verlag.*
7. *B. L. Cohen: Concepts of Nuclear Physics, TATA McGraw-Hill Publishing Company Ltd.*
8. *M. G. Stabin: Radiation Protection and Dosimetry: Introduction to Health Physics, Springer.*

3.10: Radon: Exposure Risks and Measurements(*PHY2502SP10*), Credit = 4 (3+1+0)

Unit 1: The Radioactive Radon Gas

Sources of atmospheric radiation: Natural and artificial radiations, ionising radiation and its health risks, radioactive decay series

Radon and thoron: Physical and chemical properties of radon, radon progenies, thoron and its progenies, ranges of alpha particles and recoil nuclei, sources of radon in indoor environs.

Measurement units, Equilibrium ratio

Geology and radon: Radon in rocks and soil, formation and emanation of radon, transport of radon, radon concentrations at different soil depths, variations of radon and thoron with geological characteristics, radon in ground water

Unit 2: Indoor Radon Measurements

Introduction to indoor radon surveys, Sources of indoor radon: indoor radon and bedrock, indoor radon from building materials, indoor radon from household water

Distribution of indoor radon within a house, Seasonal variations of indoor radon concentrations

Origin of the radioactivity of the atmosphere in underground mines, Mapping of probability of high radon concentrations in buildings

Applications of radon emission in earth sciences: Uranium exploration, oil prospecting, delineation of faults and thrusts, exploration of geothermal sources

Unit 3: Radon-induced health effects

Radiation doses: Absorbed dose, effective dose, equivalent dose, committed dose.

Indoor radon exposure: Health risks, epidemiological studies, radon as carcinogen- lung cancer and other cancers

Dosimetry recommendations by international organisations-ICRP, Mitigation techniques

Unit 4: Radon Measurements by Etched Track Detectors

Active and passive devices (SSNTD: CR-39 and LR-115), Track formation mechanism, Etching procedures and methodology, Track visualisations, Track measurement techniques: Optical counting systems and Spark counting systems, Calibration and standardisation of etched track detectors, Radon monitoring devices based on etched track detectors, Radon exhalation rate measurements

References:

1. *H. Cember, T. Johnson: Introduction to Health Physics, 4th Edition, McGraw Hill.*
2. *F. H. Attix: Introduction to Radiological Physics and Radiation Dosimetry, Willey Interscience.*
3. *M. G. Stabin: Radiation Protection and Dosimetry: Introduction to Health Physics, Springer.*

4. *G. F. Knoll: Radiation Detection and Measurement, John Willey & Sons.*
5. *I. Kaplan: Nuclear Physics, Oxford & IBH Publishing Pvt. Ltd.*
6. *ICRP Publications (International Commission on Radiologocal Protection).*

3.11: Accretion Physics and Radiative Processes (*PHY2502SP11*), Credit = 4 (3+1+0)

Unit 1: Introduction

Accretion as a source of energy, equation of gas dynamics, adiabatic and isothermal flow in steady state; accretion in a binary system, Roche lobe over flow, Roche geometry and binary evolution, disc formation, Transport phenomenon like viscosity, viscous torques.

Unit 2: Low Angular Momentum Accretion Flow

Spherically symmetric accretion flow in steady state; Bondi accretion

Unit 3: Accretion with Angular Momentum

Steady thin disc, radial disc structure, viscosity prescription: alpha-discs, structure of steady alpha-discs, emitted spectrum, application. Thick accretion disc, local structure of the thick disc, stability, application

Unit 4: Accretion Flow around Compact Objects

Vertical integrated equations, optical thin advection dominated disc, astrophysical application

Unit 5: Radiative Processes

Basics of theory of radiation field, thermal radiation, radiative diffusion, radiative transfer theory, elementary stellar atmospheres, relativistic electrodynamics, emission of electromagnetic radiation, scattering, Brehmstrahlung, synchrotron radiation, inverse-Compton process, plasma effects

References:

1. *Juhan Frank, Andrew King & Derek raine, Accretion power in Astrophysics , Cambridge, 2002*
2. *Fulvio Melia, High Energy Astrophysics , Princeton University Press, 2009*
3. *Malcom S. Longair, High Energy Astrophysics, Cambridge University Press, 3rd Edition, 2011*
4. *Rybicki, G.B., &Lightman, A.P., Radiative Processes in Astrophysics, John Wiley, 1985.*
5. *Ulrich Kolb, Extreme Environment Astrophysics, Cambridge University Press, 2010*

3.12: General Circulation and Climate (Atmospheric Physics) (*PHY2502SP12*), Credit = 4 (3+1+0)

1. Definitions:

What do we mean by the general circulation of the atmosphere and that
by climate?

2. Historical developments:

Observation: Pre-World War and Post-WorldWar.

Theory - Haley - Hadley- Ferrel

3. Observed General Circulation

(a) Zonally averaged time mean circulation

(b) Three dimensional time-mean circulation

(c) Transient statistics

(d) Tropical circulation - Hadley cell, ITCZ, Tropical cyclones

4. Balance requirements: From observations:

(a) Equations of motion (quick review)

(b) Water balance

(c) Angular momentum balance

(d) Heat balance, radiative balance

(e) The energy cycle

5.Theory of the general circulation

(a) Understanding the time mean and zonal mean circulation

(b) Understanding non zonal time mean circulation or, theory of stationary and transient eddies.

6. Aspect of observed general circulation

(a) The Asian Summer Monsoon

7.Variability

(a) Waves in the Atmosphere and Oceans

(b) Theory of waves, equatorial waves and extra-tropical waves

(c) Intraseasonal variability

• Low frequency transients in extra tropics

•MJO

•Monsoon Intraseasonal Oscillations (MISO)

(d) The annual cycle

(e) Interannual Variations (ENSO), QBO, of Indian monsoon

(f) Longer term variations

8. Various climate feedbacks

9. Hierarchy of climate models and their performances

10. Predictability of weather and climate

References:

1. E.N. Lorenz, 1967: The Nature and Theory of the general circulationof the atmosphere. WMO(WMO-NO.218,TP 115).
2. J.P.Peixoto and A.H.Oort, 1992: Physics of Climate, American Inst. Physics, pp 507

3. A.H.Oort, 1983: Global Atmospheric circulation statistics, 1958-1973.NOAA Professional paper No. 14. U.S Dept.of Commerce.
4. S. Hastenrath, 1985: Climate and circulation of the tropics. D.Reidelpublishing company
5. H. Richl, 1979: Climate and weather in the tropics, Academic press.
6. C.P. Chang and T.N.Krishnamurti, 1987: Monsoon Meteorology.

4: Research and Publication Ethics ((*RPE2503GP*), Credit = 2 (2+0+0)

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

Modules	**Units**	**Teaching hours**
Theory		
RPE 01	Philosophy and Ethics	4
RPE 02	Scientific Conduct	4
RPE 03	Publication Ethics	7
Practice		
RPE 04	Open Access Publishing	4
RPE 05	Publication Misconduct	4
RPE 06	Databases 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 judgements 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, Plagiarism (FFP)
  4. Redundant publications: duplicate and overlapping publication, 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 interests

4. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, types
5. 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 publication 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 Discussion (2 hrs)**
    1. Subject specific ethical issues, FFP, authorship
    2. Conflict of interest
    3. Complaints and appeals: examples and fraud from India and abroad
  - **B. Software tools (2 hrs)**
    1. Use 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 od 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