Department of Physics, CUH
Syllabus for Ph.D. (Physics)
according to Choice Based Credit System (CBCS)
Effective from 2019 onwards

Course Type

- Core Course (CC)
- Discipline Centric Elective Course (DCEC)

Total Credits: 12 [2 courses with 6 credits each]
Each student has to take the core course and one of discipline centric elective courses according to the need of the researcher whether with theoretical or experimental fields.

Semester I

Course	Course Code	Course Type	Credits
Research Methodology	SPMS PHY 02 101 CC 6006	CC	6
Any one of the following courses (DCEC)*			
Computational Techniques	SPMS PHY 02 101 DCEC 5016	DCEC	6
Experimental Methods	SPMS PHY 02 102 DCEC 5106	DCEC	6
Advanced Nuclear Physics	SPMS PHY 02 103 DCEC 5106	DCEC	6
Nanotechnology and Ion beam	SPMS PHY 02 104 DCEC 5106	DCEC	6
Total Credits			12

*The courses (DCEC) will be offered by the department depending on the requirements of the research scholars/available expertise of the faculty members.

Research Methodology

Scheme Version: 2019	Name of the subject: Research Methodology	L	T	P	C
	Applicable to Programs: Ph.D. Physics	6	0	0	6
Subject Code: SPMS PHY 02 101 CC 6006	Prerequisite: None	Total hours = 90			
	Semester I				

UNIT I

Research Problems: Meaning, Motivation, Objectives and types of research, Significance of research, Research proposals and aspects, Criteria of good research, Research formulation and hypotheses, Selection and necessity of defining the problem, Literature review, Primary and secondary sources, Reviews, Treatise, Monographs, Patents.

UNIT II

Research Design: Need, Problem Definition, Variables, Research design concepts, Research design process, Research Modeling: Types of models, Model building and stages, Data collection, processing and analysis, Simulation techniques using computer software(s).

UNIT III

Design and Planning of Experiments: Aims and objectives, expected outcome, methodology to be adopted, importance of reproducibility of research work, Interpolation, Extrapolation, Types of errors (rounding, truncation, machine and random), Error analysis and least square curve fitting. Analysis of Variance components (ANOVA) for fixed effect model, Objectives and basic principles of designs of experiments. Complete randomized design (CRD), Randomized block design (RBD) and Latin square design (LSD).

UNIT IV

Data mining and Report Writing: Library resources, Internet, Scientific search engines, Introduction to Latex/Google docs, Structure and component of research paper, Presenting the research paper/thesis, Journal impact factor, Citation index, References and bibliography, Copyright, Plagiarism and ethics in research, Communication and presentation.

Suggested Readings:

1. **C.R. Kothari, G. Garg,** Research Methodology: Methods and Techniques, New Age International Publishers, 3rd Edition, 2014.
2. **Michal Alley,** The Craft of Scientific Writing, Springer, 4th Edition, 2018.
3. **R. Pannerselvan,** Research Methodology. Prentice Hall of India, New Delhi, 2nd Edition, 2009.
4. **Y. K. Singh,**. Fundamental of Research Methodology and Statistics. New Age International Publishers, 1st Edition, 2008.
5. **D. C. Montgomery,** Design and Analysis of Experiments, Wiley, 8th Edition, 2013.
6. **K. Prathapan**, Research Methodology for Scientific Research. IK International, 1st Edition, 2014.

Computational Techniques

Scheme Version: 2019	Name of the subject: Computational Techniques	L	T	P	C
	Applicable to Programs: Ph.D. Physics	5	0	1	6
Subject Code: SPMS PHY 02 101 DCEC 5016	Prerequisite: None	Total hours = 90			
	Semester I				

UNIT I

Introduction
Overview of computer organization, Operating Systems, interfacing, hardware, workstation, servers and software used in programming, scientific programming in FORTRAN and C, C++ languages, subroutines, arrays , matrices, functions and usage of library files..

UNIT II

Numerical Techniques
Sorting interpolation, extrapolation, regression, numerical integration, quadrature, random number generation, linear algebra and matrix manipulations, inversion, diagonalization, eigenvectors and eigenvalues, integration of initial-value problems, Euler, Runge-Kutta, and Verlet schemes, root searching, optimisation, fast Fourier transform.

UNIT III

Simulation Techniques
Monte Carlo methods, molecular dynamics, simulation methods for the Ising model and atomic fluids, simulation methods for quantum-mechanical problem, time-dependent Schrödinger equation, discussion of selected problems in percolation, cellular automata, nonlinear dynamics, traffic problems, diffusion-limited aggregation, celestial mechanics, etc.

UNIT IV

Parallel Computation
Introduction to parallel computation., shared and distributed memories, automatic versus manual parallelization, partitioning, communication and synchronization of parallel program, Examples of parallel program

1. **V. Rajaraman,** Computer Programming in Fortran 90, Prentice Hall of India, 1st Edition,1997.
2. **W. H. Press, B. P. Flannery, S. A. Teukolsky and W. T. Vetterling,** Numerical Recipes in FORTRAN: The Art of Scientific Computing. (Similar volumes in C, C++)., Cambridge University Press, 3rd Edition, 2007.
3. **H. M. Antia,** Numerical Methods for Scientists and Engineers, Birkhauser, 2nd Edition, 2002.
4. **D. W. Heermann,** Computer Simulation Methods in Theoretical Physics, Springer, 2nd Edition, 1995.

5. H. Gould and J. Tobochink, An Introduction to Computer Simulation Methods, Addison-Wesley; 3rd Edition, 2006.
6. J.M. Thijssen, Computational Physics, Cambridge University Press, 1st Edition, 1999.
7. M. P. Allen, Computer Simulation of Liquids, Oxford University Press,2nd Edition , 2017.
8. D. Frenkel and B. Smit, Understanding Molecular Simulation, Academic Press,2nd Edition,2001.
9. Kurt Binder and Heerman, Monte Carlo Simulation in Statistical Physics,Springer,6th Edition,2019.

Experimental Methods

Scheme Version: 2019	Name of the subject: Experimental Methods	L	T	P	C
	Applicable to Programs: Ph.D. Physics	5	0	1	6
Subject Code: SPMS PHY 02 102 DCEC 5016	Prerequisite: None	Total hours = 90			
	Semester I				

UNIT I

Vacuum Technology: Production and Measurement of Rough to Ultra High Vacuum; various vacuum ranges, applications of vacuum technology, pressure and mean free path, Design of vacuum systems; Leak detection methods, Vacuum Materials.

UNIT II

Thin Film Technology: Synthesis of thin films for research and technological applications, Electrodeposition, Chemical vapor deposition, cluster interaction deposition, choice of thin film substrates etc, Thermal evaporation and sputtering.

UNIT III

Photon and Electron beam based techniques for surface analysis: Auger Electron spectroscopy (AES): Basic Principle, methodology and Instrumentation,. Applications of AES in Composition analysis and depth profiling. X-ray photoelectron spectroscopy (XPS) or ESCA: Principle, Instrumentation, Methodology, Quantitative analysis and Applications. Glancing angle X-ray diffraction, Basic concept, Instrumentation methodology and structural analysis applications.

UNIT IV

Techniques for surface structure and composition analysis:

Scanning electron Microscopy (SEM): Principle, Instrumentation, Methodology and Applications. Transmission Electron Microscopy (TEM): Principle, Instrumentation, Methodology for plain view and cross-sectional analysis, Applications in structural analysis. Atomic Force Microscopy (AFM): Basic principle, Methodology, typical applications in structural analysis. Energy Dispersive X-ray Flourescence: Principle, Instrumentation, Methodology and Applications**.**

References

1. **A. Roth**, “Vacuum Technology”, North Holland, 1st Edition, 2012.
2. **K.L. Chopra**, Thin film phenomena, McGraw Hill, New York, 1st Edition, 1969.
3. **L. C. Feldman and J. W. Mayer**, Fundamentals of surface and thin film analysis, North Holland, 1st Edition, 1986.
4. **Douglas A Skoog et al** , Principles of Instrumental Analysis, Cengaga, 6th Edition, 2014.
5. **C. R. Brundee and A. D. Baker**, Electron spectroscopy : Theory, techniques and applications, Academic Press London, 1st Edition, 1977.

Advanced Nuclear Physics

<table>
<tr><td rowspan="2">Scheme Version: 2019</td><td>Name of the subject: Advanced Nuclear Physics</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>Applicable to Programs: Ph.D. Physics</td><td>5</td><td>1</td><td>0</td><td>6</td></tr>
<tr><td rowspan="2">Subject Code: SPMS PHY 02 103 DCEC 5106</td><td>Prerequisite: None</td><td colspan="4">Total hours = 90</td></tr>
<tr><td colspan="5">Semester I</td></tr>
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UNIT I

Low Energy Nuclear Physics: Nuclear structure and properties, Nuclear spectroscopy, Nuclear shapes, Nuclear forces, Heavy ion collisions; Skyrme Energy Density Formalism, Theory of low energy Nuclear reactions; Quantum Mechanical Fragmentation Theory, Physics of radioactive ion beams, Nuclear astrophysics, Physics of nuclei near drip line and strange matter, Island of stability in superheavy region, Cluster radioactivity and super asymmetric fission.

UNIT II

Intermediate Energy Nuclear Physics: Heavy Ion Collisions, Multifragmentation, Elliptical Flow, Transverse Flow, Experimnetal Scenario, Subthreshold Particle production, Time dependent Hartree Fock Theory, Vlasov Uehling Uhlenbeck and Boltzmann Uehling Uhlenbeck Theory, Statistical Models, Quantum Molecular Dynamics Model, Isospin Quantum Molecular Dynamics Model, Minimum Spanning Tree and Simulated Clusterization Algorithms, Monte Carlo Simulation Techniques.

UNIT III

High Energy Nuclear (Particle) Physics: Fundamental particles and Interactions, Conservation laws and invariance principles, Standard Model, SU(2) and SU(3) Symmetries and its breaking, Feynman Diagrams, Nucleons and pions, Quark model of Hadrons, Quantum Chromo dynamics(QCD), Leptons: Neutrinos and their Oscillations, Atmospheric and Solar neutrinos, Mass Hierarchy and neutrinos masses, Neutrino's oscillations probability calculations.

UNIT IV

High Energy Astrophysics :
Stellar evolution, Black hole spin, Propagation of cosmic rays, Accretion disks in AGN, Magnetic reconnection, Physics of GRBs,. Quasar feedback, shock acceleration, neutron stars, and pulsars., gravitational wave astronomy, Properties of External Galaxies.

References :

1. **W. Greiner** and **R. K. Gupta**, Heavy elements and related phenomena, World Scientific, 1st Edition, 1999.
2. **D. Vautherin and D. M. Brink**, Phys. Rev. **C 5** (1972) 626
3. **J. Aichelin** Phys. Rep. **202**, 233(1991); C. Hartnack et al., Eur. Phys. J **A 1**, 151(1998).
4. **D. H. Perkins**, Introduction to High Energy Physics, Cambridge University Press, 4th Edition, (2000).
5. **Burcham and Zoes,** Introduction to Nuclear & Particle Physics, John Wiley & Sons Inc, 2nd Edition, 1995.
6. **James Binney**, Galactic Dynamics, Princeton University Press, 2nd Edition, 2008.
7. **Stephen Rosswog** , Introduction to high energy physics, Cambridge University Press, 1st Edition, 2011.

Nanotechnology and Ion beam

Scheme Version: 2019	Name of the subject: Nanotechnology and Ion Beam	L	T	P	C
	Applicable to Programs: Ph.D. Physics	5	1	0	6
Subject Code: SPMS PHY 02 104 DCEC 5106	Prerequisite: None	Total hours = 90			
	Semester I				

UNIT I

Introduction to Nano science: Classification of Nano materials, Size dependence of properties, Energy Bands, Chemical Mechanical, Magnetic, Structural, Optical (linear & non-linear) properties of nanoparticles. Emergence of nanotechnology: Bottom-up & Top-down approach.

UNIT II

Basic ion bombardment processes in solids: General phenomenon, ion penetration and stopping, ion range parameters, Channelling, Components of an ion implanter. Energy deposition during radiation damage, Sputtering process and Ion beam mixing, Surface modification in metals and polymeric materials due to ion irradiation with examples.

UNIT III

Ion beam applications in Nanoscience: Nano-patterning, ion beam mixing, Ball milling technique and synthesis using vacuum deposition, Advances in defect and material characterization, Materials for energy, Materials modifications in nanoparticles, thin films and multilayers

UNIT IV

Ion Beam Techniques: Synthesis, Modification and Processing of novel Materials; Ion beam analysis- SIMS, RBS, Channeling, ERDA.

References:

1. **G. Dearnally**, Ion Implantation, Annual Review of Materials Science, Volume 4, 1974 pp 93-123
2. **James F. Ziegler**, Ion implantation: Science & Technology, Academic Press, 1st Edition, 1984.
3. **J. S. Williams**, Materials Modification with Ion Beams, Reports on Progress in Physics 49(1986)491-587
4. **Guozhong Cao and Guozhong Cao**, Nanostructures & Nanomaterials-Synthesis, Properties & Applications-, Volume 2, World Scientific Publisher, 2nd Edition, 2011.
5. **Kamali Kannangara Geoff Smith, Michelle Simmons and B, Raguse**,, Nanotechnology-Basic Science and Emerging Technologies, CRC Press, 1st Edition, 2002..
6. **Michael Köhler and Wolfgang Fritzsche**, Nanotechnology- An Introduction to Nanostructuring Techniques- Wiley, 1st Edition, 2008.
7. **A. S. Edelstein and R C Cammarata** , Nanomaterials- synthesis, Properties & application, CRC Press, 1st Edition, 1998.
8. **Charles P. Poole. Jr. and Frank J. Qwens**, Introduction to Nanotechnology, John Wiley & Sons, 1st Edition, 2003.