Ph.D. course					21PH701T- Laser and its Interaction with matter					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					IA	**MS**	**ES**	**LW**	**LE/Viva**	
3	**0**	**0**	**3**	**3**	**25**	**25**	**50**	**--**	**--**	**100**

COURSE OBJECTIVES

- To understand the fundamental concepts of Laser principles.
- To provide the knowledge of Laser beam properties and methods of Laser pulse generation
- To provide knowledge of Laser matter interaction
- To introduce some applications of involving Laser-matter interaction

UNIT 1 Introduction to Lasers	**10 Hrs.**
History of Laser; Classical absorption of light; Quantum absorption of light; Interaction of Light with matter: Absorption and Emission processes; Light Source; Properties of Laser, Einstein Coefficients and Light Amplification; Population Inversion; Pumping; Gain.	
UNIT 2 Fundamentals of Laser	**12 Hrs.**
Laser rate equations; Three & four level Lasers; Laser beam propagation; Properties of Gaussian beam; Resonator; Various types of resonators; Resonator for high gain and high energy Lasers; Gaussian beam focusing; General lasers and their types: CW and pulsed Lasers; Laser pulse generation: Q-switching and mode locking; ultra-short (nanosecond, picosecond and femtosecond) laser pulse generation.	
UNIT 3 Laser matter interaction	**10 Hrs.**
Basics of Laser-matter interaction, Spectral Emission from Laser produced Plasma: Continuum Emission, Line Emission, Temporal and Spatial Resolution of Emission, Processes in Laser Produced Plasma, Plasma Ignition Processes, Plasma Expansion Processes, Plasma Emission Spectra, Electron Density and Plasma Temperature, Particle Formation Processes, Particle Ejection, Nanoparticle Formation, Laser Ablation Parameters.	
UNIT 4 Some applications involving Laser-matter interaction	**10 Hrs.**
Laser systems for spectroscopy; Instrumentation for detection of optical signals and time-resolved measurements; Raman spectroscopy: basics and instrumentation, Laser-induced breakdown spectroscopy; Terahertz spectroscopy; Laser micro-machining, Lithography, Laser welding, Some future prospects	
	Max. <42> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Acquire basic knowledge about the fundamental processes associated with Lasers
CO2 - Analyze the properties of the Laser beam and solve related problems

CO3 - Comprehend the significance of Laser and its interaction with matter
CO4 - Understand and learn the principles involved in Laser-matter interaction
CO5 - Correlate the Laser properties with various applications
CO6 - Develop the skills needed to solve various problems in applications related to laser and its interaction with matter

TEXT/REFERENCE BOOKS

1. O Svelto, Principles of lasers, 5th edition, Springer (2010).
2. W. T. Silfvast, Laser Fundamentals, 2nd Edition, Cambridge University Press (2004).
3. K. Thyagrajan and Ajoy Ghatak, LASER fundamentals and its applications, 2nd edition, Springer (2010).
4. Andrews and Demidov, An introduction to Laser Spectroscopy, 2nd edition, Springer (2002).
5. Demtroder W, Laser Spectroscopy: Basic Concepts and Instrumentation, 3rd edition, Springer (2004)
6. Radziemski L J, Solarz R W, Paisner J A, Laser Spectroscopy and its Applications, Marcel Dekker (1987)
7. Stenholm, Foundations of laser spectroscopy, Wiley (1999).
8. Jagdish P. Singh, and Surya Narayan Thakur, Laser-induced breakdown spectroscopy. Elsevier (2007).

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A/Question: 3 Questions from each unit, each carrying 3 marks	36 Marks
Part B/Question: 2 Questions from each unit, each carrying 8 marks	64 Marks

21PH702T Modelling &Simulation in Atmospheric Science										
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory		Tutorial	Term Work	Practical	Total Marks
					IA	ES				
3	0	0	3	3	50	50	--	--	--	100

COURSE OBJECTIVES

- To acquire the basic knowledge of concepts of Density functional theory.
- To learn and adopt various relevant computational packages.
- To appreciate the role of atmospheric models for large scale weather and climate predictions.
- To make understand major atmospheric phenomena and their impacts on the Climate and vice versa.

UNIT I Introduction to DFT **12 Hrs.**

Basics of DFT, Comparison with conventional wave function approach, Hohenberg-Kohn Theorem;Kohn-Sham Equation; Thomas-Fermi approximation and beyond; Practical DFT in a many bodyCalculation and its reliability.

UNIT II Introduction to Atmospheric Physics. **10 Hrs.**

Atmospheric composition and its structure, Atmospheric dynamics (General circulation of atmosphere and oceans), Aerosols (source, sink and properties), Cloud and rain formation, Observation of meteorological parameters from ground and satellite, Greenhouse effect, Climate change and its effect.

UNIT III Computational Packages **12 Hrs.**

Introduction to matlab programming, First principle abinto calculations, Quantum Espresso, Gaussian 9.0c and Gauss view

UNIT IV Global and Regional Climate **10 Hrs.**

Basics of modeling in atmospheric science, Basic equation and dynamics of atmosphere, Computational techniques through Matlab, Introduction of atmospheric modeling using Matlab, Handling of satellite data, Elementary idea of global climate models.

Max. 44 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to
CO1 - Enumerate the basic concepts of electronic structure of the materials. .
CO2 - Discuss various basic theorems for density functional theory.
CO3 – Demonstrate an ability to use various packages for atmospheric problems.
CO4 - Apply understanding of atmospheric measurements to understand atmospheric variations.
CO5 - Generate equation of motion and continuity for the atmospheric modelling.
CO6 - Analyze effect of global warming of the present and future atmosphere.

Text Books

1. Lutgens F.K., Tarbuck E.J. and Tasa D.G. : The Atmosphere (Pearson)
2. Electronic structure: theory and applications by R. Martin

Reference Books

1. Salby, M.L.: Fundamentals of Atmospheric Physics (Academic Press)
2. Holton, J.R.: An Introduction to Dynamic Meteorology (Academic Press)
3. Iribarne, J.V. and Godson, W.L.: Atmospheric Thermodynamics (D. Reidel)
4. Thomson, P.D.: Numerical Weather Analysis and Prediction (Macmillan)
5. Andrews, D.G.: An introduction to atmospheric physics (Cambridge University press)
6. Liou, K.N.: An introduction to atmospheric radiation (Academic press)
7. Houghton, J.T., Taylor, F.W., and Rodgers, C. D.: Remote Sensing of Atmosphere (Cambridge Univ. Press)
8. Seinfeld, J.H., Pandis, S.N.: Atmospheric Chemistry and Physics (Wiley)

Ph.D. course					21PH703T Advanced Characterization Techniques					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
3	**0**	**0**	**3**	**3**	**25**	**50**	**25**	**--**	**--**	**100**

COURSE OBJECTIVES

- To introduce the various advanced techniques for the materials characterization.
- To provide the basics and working of diffraction techniques and electron microscopy.
- To introduce the principles and methods of various spectroscopic and other characterization techniques.
- To provide the basic understanding of data analysis and operation of different characterization equipments.

UNIT 1 Introduction to characterization techniques	**8 Hrs.**
Introduction: Importance of advanced characterization techniques for the development of materials; Scientific understanding of phenomena in materials technology; Importance of various characterization Techniques: Optical, structural, morphological and spectroscopic.	
UNIT 2: Diffraction techniques and Electron microscopy	**10 Hrs.**
Fundamental crystallography; Generation and detection of X-rays; X-ray diffraction (XRD) techniques; XRD basics, geometry, instrumentation; Electron diffraction: Phase identification Interaction of electrons with solids; Scanning electron microscopy (SEM); Transmission electron microscopy (TEM): dark field, bright field imaging, high resolution mode; Energy dispersive spectroscopy (EDS).	
UNIT 3: Nuclear Spectroscopy	**10 Hrs.**
Types of radiation and sources, Interaction of Radiation with matter, Working and data acquisition from various types of Detectors: Solid state, gaseous, liquid, organic and inorganic. Scintillators: properties and types. Generation of particle radiation: Accelerators, LINAC, Van de Graff, Pelletron. Particle-induced gamma emission (PIGE), Proton Induced X-ray Emission (PIXE), Pulse shape discrimination (PSD), Positron Emission Tomography (PET).	
UNIT 4: Advanced spectroscopic and some other techniques	**12 Hrs.**
Advanced Spectroscopic Techniques: UV-Visible Spectroscopy; Photo-luminescence spectroscopy; Infra-red spectroscopy; Luminescence spectroscopy, Raman spectroscopy; X-ray photoelectron spectroscopy (XPS). Scanning probe techniques: Principles of Scanning Tunnelling Microscope (STM) and Atomic Force Microscope (AFM); Laser Confocal Microscopy; Vibration sample and Superconducting quantum interference device (SQUID) magnetometry; Thermal studies: TGA.	
	Max. <40> Hrs.

COURSE OUTCOMES

After completion of this course students will be able to

CO1: Demonstrate an understanding of various advanced microscopic techniques.

CO2: Develop the ability to recognize the appropriate microscopic methods and apply them to various materials to obtain desired information.
CO3: Understand the different diffraction and electron microscopic techniques and be able to analyse and determine the structure of various materials.
CO4: Acquire knowledge about the different nuclear and other advanced spectroscopic characterization techniques.
CO5: Summarise and compare the results of different advanced characterization techniques.
CO6: Analyse and interpret the data acquired from different characterization methods and come up with relevant conclusions.

TEXT/REFERENCE BOOK

1. Materials Characterisation: Introduction to Microscopic and Spectroscopic Methods, Y. Leng, John Wiley & Sons (Asia), 2013.(2nd Edition)
2. Materials characterization techniques, Sam Zhang, L. Li & Ashok Kumar, Boca Raton: CRC Press, 2009.
3. Principles of Instrumental Analysis, D.A. Skoog, F.J. Holler, S. R. Crouch, Cengage Learning, 2018 (7th Edition).
4. Experimental techniques in materials and mechanics, C. Suryanarayana, CRC Press, Year: 2011
5. Techniques for Nuclear and Particle Physics Experiments, William R. Leo, Springer Science, 1994.
6. Radiation detection and measurement, G. F. Knoll, Wiley & Sons, 4th Edition, 2008.
7. Experimental Techniques, Sam Zhang, CRC Press, 2009.
8. Elements of X-Ray Diffraction, Cullity, and Stock, Prentice-Hall, 2001.
9. Material characterization techniques, Kumar, Li, Zhang, CRC Press, 2008.

Ph.D. Course					21PH704T Nuclear, Particle and Radiation Physics					
Teaching Scheme					**Examination Scheme**					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To develop the understanding of nuclear force, two nucleon system and deuteron problem.
- To introduce properties of nuclei and details of popular nuclear models.
- To familiarize with the fundamental forces and the dynamics of elementary particles under these forces.
- To overview the radiation types and their interaction with matter in detectors and accelerators.

UNIT 1: NUCLEAR FORCE	**12 Hrs.**
Static properties of Nuclei, Nuclear size determination from electron and alpha scattering, various forms of nuclear potential, Nucleon mean potential, single particle energy levels, magic number nuclear form factors, angular momentum, spin and moments of nuclei. Two nucleon system and nuclear forces, Dipole and quadrupole moments of a deuteron, saturation property evidence, Spin dependence, exchange character, Charge independence and charge symmetry.	
UNIT 2: NUCLEAR REACTIONS AND DECAYS	**10 Hrs.**
Liquid drop and shell models of nuclei. Nuclear decay modes, Moments, excited states and other predictions from shell model, Collective model, Radioactive decay and reactions, Alpha decay, Beta decay, Gamma decay, Nuclear reactions, Nuclear Fission, Fusion, Fusion in Stars, Nucleosynthesis, Neutrinos, neutrino oscillation. Astrophysical consequences.	
UNIT 3: PARTICLE PHYSICS	**10 Hrs.**
Elementary Particles and Fundamental Forces, Quark Model, Structure of protons and neutrons, Quark model of hadrons, flavour and colour, parity violation, lepton-nucleon scattering, and structure functions, Gauge theories of strong and electroweak interactions.	
UNIT 4: RADIATION PHYSICS	**08 Hrs.**
Nuclear radiation types and sources: Characteristic X-rays, Light and heavy Charged Particles, gamma rays, neutrons. Interaction of radiation with matter, scattering theory, stopping power, attenuation coefficients, range, energy distribution, n-gamma reactions, detectors and types, accelerators.	
Max. 40 Hrs.	

COURSE OUTCOMES

After completion of this course students will be able to

CO1: Understand nuclear structure and reaction dynamics will provides knowledge of nuclear-nucleon interaction.

CO2: Identify the basic physical principles behind theoretical, phenomenological and experimental approaches commonly used in research.

CO3: Determine the basic laws of conservation and momentum in the determination of particle properties and processes in the subatomic world..

CO4: Apply their knowledge to solve a wide range of problems, with special relevance to research conducted in the department.

CO5: Determine and work on elementary problem solving in nuclear and particle physics, and relating theoretical predictions and measurement results.
CO6: Demonstrate proficiency with fundamental methods, concepts and terminology of Nuclear, particle and radiation Physics.

TEXT/REFERENCE BOOK

1. Nuclear Physics – Theory & Experiments, R.R. Roy & B.P. Nigam, New Age International, 2005.
2. Nuclear Physics by V. Devanathan. Narosa Publishing House, Delhi.
3. Nuclear Structure Vol. 1 & 2., Aaghe Bohr & Ben R. Mottelson, World Scientific.
4. Fundamentals In Nuclear Physics, Jean-Louis Basdevant, James Rich, Michel Spiro, Springer.
5. Introductory Nuclear Physics, Samuel S. M. Wong, Wiley-Vch.
6. Source Book on Atomic Energy, Samuel Glasstone, Litton Educational Publishing.
7. Introduction to Elementary Particles, D. Griffiths, Academic Press, 2nd Ed. 2008.
8. Nuclear Physics, S. N. Ghoshal, First edition, S. Chand Publication.

Ph.D. course											21PH705T Atmospheric & Environmental Physics
Teaching Scheme					**Examination Scheme**						
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Tutorial**	**Term Work**	**Practical**	**Total Marks**
					IA	**MS**	**ES**				
3	**0**	**0**	**3**	**3**	**25**	**25**	**50**	**--**	**--**	**--**	**100**

COURSE OBJECTIVES

- To introduce basics of atmosphere and physical meteorology.
- To learn observational techniques available in the field of atmospheric science.
- To overview the basics of dynamical meteorology.
- To appreciate the role of atmospheric models for large scale weather and climate predictions.
- To make understand major atmospheric phenomena and their impacts on the Climate and vice versa.

UNIT I Elements of Atmosphere and Physical Meteorology 12 Hrs.

Atmospheric composition, Scale height, laws of thermodynamics of the atmosphere, Adiabatic processes, The Clausius-Claperon equation, Laws of radiation and their implication for radiative processes, Solar and terrestrial radiation, Transport of matter, energy and momentum in nature, Type of Clouds and rain formation process, General circulation of the tropics; Indian Monsoon, Introduction to Aerosols, Rayleigh and Mie scattering, the human environment, Atmospheric Pollution.

UNIT II Dynamical Meteorology and Renewable Sources of Energy 10 Hrs.

The fundamental forces, hydrostatic equation, Wet and dry adiabatic lapse rate, Enthalpy equation, Entropy of dry air and entropy change, Energy sources and combustion processes, renewable sources of energy, Solar energy, wind energy, bioenergy, hydropower, fuel cells and nuclear energy, transportation of environmental pollutants.

UNIT III Observational Techniques in Atmospheric Physics 12 Hrs.

Conventional observational techniques, conventional measurement of pressure, temperature, humidity, wind, precipitation, visibility, Modern Observational Techniques: LIDARS, SODARS, RADARS, CTD, ARGO, Remote sensing from space.

UNIT IV Global and Regional Climate 10 Hrs.

Elements of weather and climate modelling, Basic equation and dynamics of atmosphere, General circulation of atmosphere and oceans, Global warming and climate change, Enhanced Greenhouse effect, Energy balance- a zero-dimensional Greenhouse model, Elementary idea of Global climate models, environmental issues.

Max. 44 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to
CO1 – Identify the various atmospheric processes along with their importance.

CO2 – Determine importance of atmospheric dynamics in the earth's atmosphere.
CO3 - Describe various atmosphere instrumentations such as LIDARS, satellite sensors and remote sensing image acquisition methods.
CO4 – Apply understanding of atmospheric measurements to understand atmospheric variations.
CO5 – Generate equation of motion and continuity for the atmospheric modelling.
CO6 – Analyze effect of global warming of the present and future atmosphere.

Text Books

1. Lutgens F.K., Tarbuck E.J. and Tasa D.G. : The Atmosphere (Pearson)
2. Houghton, J.T.: The Physics of Atmosphere (Cambridge Univ. Press)

Reference Books

1. Salby, M.L.: Fundamentals of Atmospheric Physics (Academic Press)
2. Vallace, J.M. and Hobbs, P.W. : Atmospheric Science: An Introductory Survey (Academic Press)
3. Holton, J.R.: An Introduction to Dynamic Meteorology (Academic Press)
4. Iribarne, J.V. and Godson, W.L.: Atmospheric Thermodynamics (D. Reidel)
5. Thomson, P.D.: Numerical Weather Analysis and Prediction (Macmillan)
6. Boeker, E & Groundelle, R.V.: Environmental Physics (John Wiley)
7. Twidell, J & Weir, J.: Renewable Energy Resources (Elbs)
8. Keshavamurty, R.N. & Shanker Rao, M.: The Physics of Monsoons (Allied Publishers, 1992)
9. Andrews, D.G.: An introduction to atmospheric physics (Cambridge University press)
10. Liou, K.N.: An introduction to atmospheric radiation (Academic press)
11. Kidder, S.Q. & Vonder Haar, T.H.: Satellite Meteorology: An Introduction (Academic Press)
12. Houghton, J.T., Taylor, F.W., and Rodgers, C. D.: Remote Sensing of Atmosphere (Cambridge Univ. Press)
13. Seinfeld, J.H., Pandis, S.N.: Atmospheric Chemistry and Physics (Wiley)

Ph.D. course					21PH706T-Mathematical Methods for Physics					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25			100

COURSE OBJECTIVES

- To understand the concepts of Fourier analysis and its applications.
- To understand Laplace transforms, differential equations and calculus of variations.
- To understand the concepts of vector calculus, vector spaces and applications.
- To understand the methods complex analysis for integration and conformal mapping.
- To introduce the concept of probabilistic random variables and their applications.
- To introduce the concept of statistical sampling, estimation methods, and hypothesis testing.

UNIT 1 Fourier analysis and transforms	**10 Hrs.**
Fourier Seies, Dirichlet conditions, Fourier coefficients, discontinuous functions, non-periodic functions, Complex fourier series, Parseval's theorem, Fourier Integral and Transforms, Properties, convolution and deconvolution, relation of Dirac Delta function to Fourier Transform, Parseval's theorem, Fourier transform in higher dimensions. Applications.	
UNIT 2 Laplace Trasforms, HDEs, PDEs & Calculus of Variations	**8 Hrs.**
Laplace Transforms of a functions, derivatives and integrals, other properties, applications to solving differential equations, Higher order differential equations, partial differential equations, general and particular solutions, Calculus of Variations, Euler-Lagrange Equations, Physical Examples.	
UNIT 3 Vector calculus , Complex analysis, Vector Spaces and Matrices	**12 Hrs.**
Vector calculus in single and multiple variables, gradients, divergence, curl, line integral, Green's theorem, surface integral, Stoke's Theorem, Applications. Complex Analytic Functions, Complex Integrals, Laurent Series, Complex Integration by Method of Residues, Conformal Mapping and Applications. Vector Spaces, Linear Independence, Linear Transformations, Matrices & Determinants, Similarity Transformation, Inner Product, Orthogonality, Completeness, Orthonormality, Transformations, Diagonalization, Applications to Physics Problems.	
UNIT 4 Probability theory and Statistics	**10 Hrs.**
Probability axioms and theorems, permutations and combinations, random variables and distributions, properties of distributions, Functions of random variables, generating functions, central limit theorem, Joint distributions. Statistical experiments, samples and populations, sample statistics, estimators and sampling distributions, maximum likelihood estimate, least squares.	
	Max: 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – apply Fourier Series/Integral/Transform methods to various problems of Physics.

CO2 – apply the Laplace transforms, differential equations & calculus of variations to Physics problems. .

CO3 – apply the methods of vector calculus and vector spaces in Physics. .

CO4 – use complex analysis methods to solving integrals not solvable by regular methods in the Sciences.

CO5 – apply the concepts of probability and random variable to various problems in Physical Sciences.

CO6 – apply the methods of statistics to estimate the parameters for data in problems of Physical Sciences. .

TEXT/REFERENCE BOOKS

1. K. F. Riley, MP Hobson, SJ Bence,Mathematical Methods for Physics and Engineering 3rd ed., Cambridge 2006.
2. Mary L. Boas, Mathematical Methods for the Physical Sciences, John Wiley and Sons Inc. 2006
3. F. W. Byron and R. W. Fuller, Mathematical Methods for Classical and Quantum Physics, Dover Publishing, 1992.
4. E. Kreyszig, Advanced Engineering Mathematics 9th ed, John wiley & sons.
5. Arfken and Weber, Mathematical Methods for Physicists 6th ed. Elsevier (2005).
6. Earl A. Coddington, An Introduction to Ordinary Differential Equations. Prentice-Hall India (1968).
7. Mark J. Ablowitz and Athanassios S. Fokas Complex Variables: Introduction and Applications (Cambridge Texts in Applied Mathematics), Cambridge, 2003).
8. Tristan Needham, Visual Complex Analysis. Oxford University Press (1999).

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A/Question: 10 Questions from each unit, each carrying 2 marks	20 Marks (30 mins)
Part B/Question: 5 Questions from each unit, each carrying 6 marks	30 Marks (60 mins)
Part C/Question: 5 Question from each unit , each carrying 10 marks	50 Marks (90 mins)

Ph.D. course					21PH707T Plasma Physics and Fusion Science					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
3	**0**	**0**	**3**	**3**	**25**	**50**	**25**			**100**

COURSE OBJECTIVES

- To understand the general properties of Plasma, the fourth state of matter.
- To understand the single particle charge dynamics.
- To introduce the basic concepts of magnetohydrodynamics.
- To introduce various Plasma Diagnostics Techniques
- To introduce the techniques of Plasma production and applications.
- To introduce the Tokamak Technology for Plasma Confinement.

Unit 1 Basics of Plasma	10 Hrs
Basic plasma concept: Definition & Characteristics of Plasma, Plasma frequency, Debye shielding, plasma sheath.The Plasma Frequency, The Occurrence of Plasmas in Nature, Applications of Plasma Physics, Theoretical Description of Plasma Phenomena. **Gas Discharge processes:** Ionization, Townsend ionization coefficient, Paschen law, breakdown criterion, space charge of avalanche, Streamer formation, temporal development of breakdown, Glow discharge. **Single Particle Motion:** Lorentz force, Motion of charged particle in uniform Magnetic Field (Gyro Motion), Uniform Magnetic and Electric Field (E x B Drift), particle motion in non-uniform Magnetic Field (Gradient and Curvature Drift, Magnetic Mirror), Motions in a Dipole Magnetic Field, Adiabatic Invariants.	
Unit 2: Magneto hydrodynamics and Plasma Diagnostics:	**10 Hrs**
The Equations of MHD Equations, Ideal & resistive MHD, Magnetic Pressure, Magnetic Field Convection and Diffusion, Magnetic Reconnection, Alfven & Whistler waves, Kink instability. Plasma Diagnostics: Electric & Magnetic probes, Spectroscopy-Passive and Active, Microwave and Laser, Soft x-ray & Hard x-ray, Fusion Products, Erosion, Dust & Tritium monitor.	
Unit 3: Plasma production and applications:	**10 Hrs**
dc discharge, rf discharge, photo-ionization, tunnel ionization, avalanche breakdown, laser produced plasmas, Langmuir probe. Medium and short wave communication, plasma processing of materials, laser ablation, laser driven fusion, magnetic fusion.	
Unit 4: Tokamak & Plasma Wall Interactions:	**10 Hrs**
Components and Sub systems of Tokamak and their functions, concept of tokamak Reactor, Safety factor, Rotational Transform, Magnetic Shear, Beta parameter, q-Limit, density–Limit, Hugill Diagram Tokamak Equilibrium and Pressure Balance. Plasma Heating: Ohmic Heating, Electromagnetic Wave Heating, ICRH, LHRH, ECRH, NBI. Fueling of Tokamak Plasma. Plasma Wall Interaction: Recycling and Wall Pumping, Wall Conditioning, Boundary of Plasma: SOL, Role of Limiter and Diverter, Limiter Types, Diverter Configurations, Steady State Operation of Tokamak: Introduction to SST-1, ITER and DEMO.	
Total : 40 Hours	

COURSE OUTCOMES

On completion of the course, student will have the
CO1 – understanding of the general properties of Plasma, the fourth state of matter.
CO2 – Understanding of single particle charge dynamics.
CO3 – Understanding of the d the basic concepts of magnetohydrodynamics.
CO4 – knowledge of the various Plasma Diagnostics Techniques
CO5 – knowledge of the techniques of Plasma production and applications.
CO6 – knowledge of Tokamak Technology for Plasma Confinement.

Textbooks and References:

1) Goldston, R. J., and P. H. Rutherford. *Introduction to Plasma Physics*. Philadelphia, PA: IOP Publishing, 1995.
2) J.A. Bittencourt, Fundamentals of Plasma Physics, Springer, 2004
3) Krall, N. A., and A. W. Trivelpiece. *Principles of Plasma Physics*. Berkeley, CA: San Francisco Press,
4) Wesson, J. *Tokamaks*. 3rd ed. Oxford, UK: Oxford University Press, 2004
5) Stix, T. H. *Waves in Plasmas*. New York, NY: Springer, 1992.
6) Miyamoto, K. *Plasma Physics for Nuclear Fusion*. Cambridge, MA: MIT Press, 1989
7) A. M. Howatson, An Introduction to Gas Discharge.
8) Yuri P. Raizer, Gas Discharge Physics
9) D. A. Gurnett and A. Bhattacharjee, Introduction to Plasma Physics, Cambridge, 2005.
10) Francis F Chen, Introduction to Plasma Physics and Controlled Fusion, Volume 1: Plasma Physics, Plenum Press, 1984.
11) I.H. Hutchinson, Principles of Plasma Diagnostics
12) John Wesson (UKAEA), Tokamaks

22PH701T					Advanced Electronic Materials and Devices					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	0	3	50	50	0	0	0	100

COURSE OBJECTIVES

14. To develop the fundamental understanding of organic and hybrid semiconductors.
15. To develop the understanding of organic device fabrication and characterizations
16. To provide the comprehensive knowledge of the charge transport mechanism in organic.
17. To analyse the processing and optical and electrical characteristics of various advanced electronic devices

UNIT 1 Introduction to Organic and Hybrid Semiconductors **12 Hrs.**

Organic Semiconductors: Introduction, electronic states in conjugated molecules, electronic transport in crystalline organic materials and conductive polymers, charge injection at metal/organic interface, hybrid perovskite materials, structure, stability and challenges.

UNIT 2 Processing of Organic Materials and Devices **8 Hrs.**

The essential characteristic of the electrode materials for organic electronic devices, charge transport layers (HTL/ETL), processing vs morphology and optical/structural/electrical properties, understanding of optoelectronic properties, flexible electronics.

UNIT 3 Optoelectronic Devices and Physics **12 Hrs.**

The basic structure of organic devices, Bulk-heterojunction Inverted, and Tandem organic photovoltaic (OPV) devices; Carrier loss mechanisms in OPVs; Nanomorphology Dye-sensitized solar cells, organic solar cells, hybrid perovskite solar cells, OLEDs and PLEDs, operating principles of organic lasers.

UNIT 4 Other Electronic Devices **8 Hrs.**

Fundamentals of various data storage materials, hybrid perovskite memory devices, materials and switchng mechanism, fundamentals and advances of artificial synapeses and their characteristics.

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Explain the difference between organic, inorganic and hybrid electronic materials.

CO2 – Analyze of the charge transport phenomenon in organic and hybrid materials

CO3 – Explain the structural, optical and electrical properties of organic and hybrid thin-films.

CO4 – To explain and analysis different organic and hybrid device processing

CO5 – Explain the operating principle and efficiency limitations in various solar cells, OLED, laser, memory and artificial synaptic devices.

CO6 – Design and analysis of the organic/hybrid electronic devices.

TEXT/REFERENCE BOOKS

- Suganuma Katsuaki, Introduction to Printed Electronics, Springer, 2014.
- Stergios Logothetidis, Handbook of Flexible Organic Electronics - Materials, Manufacturing, and Applications, 1st Ed., Woodhead Publishing, 2014.
- **Park**, Nam-Gyu, **Grätzel**, Michael, **Miyasaka**, Tsutomu, Organic-Inorganic Halide Perovskite Photovoltaics, springer publishing group, 2016.
- Anna Köhler and Heinz Bässler, Electronics Processes in Organic Semiconductors - An Introduction, 1st Ed., Wiley-VCH, 2015.
- Wenping Hu, Organic Optoelectronics, 1st Ed., Wiley-VCH, 2013.
- Sam-Shajing Sun and Larry R. Dalton, Introduction to Organic Electronic and Optoelectronic Materials and Devices, 2nd Ed., CRC Press, 2015.
- Franky So, Organic Electronics: Materials, Processing, Devices, and Applications, CRC Press, 2010

<table>
<tr><td colspan="5">Ph.D. Course : 22PH702T</td><td colspan="6">Fundamentals and Application of Vacuum Science and Thin Film Technology</td></tr>
<tr><td colspan="5">Teaching Scheme</td><td colspan="6">Examination Scheme</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">C</td><td rowspan="2">Hrs/Week</td><td colspan="3">Theory</td><td colspan="2">Practical</td><td rowspan="2">Total Marks</td></tr>
<tr><td>MS</td><td>ES</td><td>IA</td><td>LW</td><td>LE/Viva</td></tr>
<tr><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td><td>25</td><td>50</td><td>25</td><td>--</td><td>--</td><td>100</td></tr>
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COURSE OBJECTIVES

18. To understand the fundamentals of Vacuum Science and Thin Film Technology.
19. To identify the difference among various physical deposition techniques and apply them for development of devices.
20. To critically analyze nucleation and growth patterns.
21. To apply chemical techniques for thin film deposition.
22. To evaluate the quality of thin films for device applications.

UNIT 1 Fundamentals of Vacuum Technology **14 Hrs.**

Behavior of Gases, Gas Transport Phenomenon, Viscous, molecular and transition flow regimes Production of Vacuum, Mechanical Pumps(rotary, turbo molecular pumps), Diffusion pump, Getter and Ion pumps, Cryopumps, Materials in Vacuum; High Vacuum, and Ultra High Vacuum Systems; Leak Detection; Measurement of Pressure, Pirani penning gauge, Residual Gas Analysis.

UNIT 2 Physical Vapor Deposition Technology **15 Hrs.**

Physical Vapor Deposition – Hertz Knudsen equation; mass evaporation rate; nudsen cell, Directional distribution of evaporating species Evaporation of elements, compounds, alloys, Raoult’s law; e-beam, pulsed laser and ion beam evaporation, reactive evaporation, Glow Discharge and Plasma, Sputtering– mechanisms and yield, dc and rf sputtering, Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering.

UNIT 3 Chemical Techniques for Thin Film Deposition **15 Hrs.**

Chemical Vapor Deposition - reaction chemistry and thermodynamics of CVD; Thermal CVD, plasma enhanced CVD for amorphous silicon thin films, Other Chemical Techniques - Spray Pyrolysis, Electrodeposition, Sol-Gel technique.

UNIT 4 Fundamentals and Applications of Nucleation and Epitaxial Growth **15 Hrs.**

Nucleation & Growth: capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth, stages of film growth & mechanisms, Epitaxy–homo, hetero and coherent epilayers, lattice misfit and imperfections, epitaxy of compound semiconductors, scope and applications of thin films in photovoltaic and other electronic devices.

Max. <59> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Understand the fundamentals of Vacuum Science and Thin Fim Technology.

CO2 - Identify the difference among various physical deposition techniques and apply them for development of devices.

CO3 - Critically analyze nucleation and growth patterns.

CO4 - Apply the chemical techniques for thin film deposition.

CO5 - Evaluate the quality of thin films.

CO6 – Analyze and apply suitable technique for device fabrication.

TEXT/REFERENCE BOOKS

9. James M. Lafferty, Foundations of Vacuum Science and Technology
10. J.F. O’Hanlon, A User’s Guide to Vacuum Science and Technology
11. Rao, Ghosh and Chopra, Vacuum Science and Technology
12. Milton Ohring, Materials Science of Thin Films, Second Edition
13. Joy George, Preparation of Thin Films, Published by Marcel Dekker
14. Dr. Brijesh Tripathi, Dr. Manoj Kumar, Solar Energy From Cells To Grid, CSMFL Publications, 2018

15. Maurice H. Francombe, Handbook of Thin Film Devices, Elsevier Inc. ISBN: 978-0-12-265320-9

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100	**Exam Duration: 3 Hrs**
Part A/Question: 3 Questions from each unit, each carrying 3 marks	36 Marks
Part B/Question: 2 Questions from each unit, each carrying 8 marks	64 Marks

Ph.D. Course : 22PH703T					Fundamentals and Applications of Solar Energy Technology					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
4	0	0	4	4	25	50	25	--	--	100

COURSE OBJECTIVES

23. To understand the fundamentals of Energy received from Solar Radiation.
24. To apply the methods for photovoltaic and thermal energy generation.
25. To critically analyze Economics of Grid-connected Photovoltaic Power Plant.
26. To identify the critical issues in designing of a one Megawatt Solar photovoltaic power plant.
27. To evaluate Government schemes for renewable energy promotion.

UNIT 1 Energy from Solar Radiation **14 Hrs.**

Energy Scenario, overview of solar energy conversion devices and applications, physics of propagation of solar radiation from the sun to earth, Sun-Earth Geometry, Extra-Terrestrial and Terrestrial Radiation, Solar energy measuring instruments, Estimation of solar radiation under different climatic conditions, Estimation of total radiation.

UNIT 2 Concept of Solar Photovoltaic Electricity Generation **15 Hrs.**

Fundamentals of solar PV cells, principles and performance analysis, modules, arrays, theoretical maximum power generation from PV cells, Third generation concepts for photovoltaic energy generation, PV standalone system components, Standalone PV-system design, One axis tracking, Double axis tracking.

UNIT 3 Economics of Grid-connected Photovoltaic Power Plant **15 Hrs.**

Components of grid-connected PV system, solar power plant design and performance analysis, PVsyst Software, Exercise on designing of a one Megawatt Solar photovoltaic power plant, schedule and unscheduled maintenance, spare parts, performance monitoring evaluation and optimization, contracts, Economics and financial modeling: economics benefits and costs, (Central electricity regulatory commission) CERC cost benchmarks, financial model, power purchase agreement (PPA), renewable energy certificates (REC), risk and insurance and documentation required for Solar power plant.

UNIT 4 Fundamentals and Applications of Solar Thermal Technology **15 Hrs.**

Fundamentals of solar collectors, Snails law, Bougers law, Physical significance of Transmissivity – absorptivity product, Performance analysis of Liquid flat plate collectors and testing, Performance analysis of Solar Air heaters and testing, Solar thermal power generation (Solar concentrators), Thermal Energy Storage (sensible, latent and thermochemical) and solar pond, Applications: Solar Refrigeration, Passive architecture, solar distillation, and emerging technologies..

Max. <59> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Understand the fundamentals of Energy received from Solar Radiation.

CO2 - Analyze the methods of solar photovoltaic and thermal energy generation and apply suitable technique for solar tracking.

CO3 - Critically analyze Economics of Grid-connected Photovoltaic Power Plant.

CO4 - Apply the methods for photovoltaic and thermal energy generation.

CO5 - Evaluate the Government schemes for renewable energy promotion.

CO6 - Identify the critical issues in designing of a one Megawatt Solar photovoltaic power plant.

TEXT/REFERENCE BOOKS

1. G. N. Tiwari, Solar Energy, Fundamentals, Design, Modeling and Applications, Narosa, 2002.
2. S. P. Sukhatme and J. K. Nayak, Solar Energy: Principles of Thermal Collection and Storage, Tata McGraw Hill, 2006.
3. C. S. Solanki, Solar Photovoltaics: Fundamentals, Technologies and Applications, Prentice Hall India, 2nd Edition, 2011.

4. J. A. Duffie and W. A. Beckman, Solar Engineering of Thermal Processes, John Wiley, 2006.
5. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, 1999.
6. H. P. Garg and J. Prakash, Solar Energy: Fundamentals and Applications, Tata McGraw Hill, 1997.
7. M. A. Green, Third Generation Photovoltaics: Advanced Solar Energy Conversion, Springer, 2003.
8. A. Goetzberger and V. U. Hoffmann, Photovoltaic Solar Energy Generation, Springer- -verlag, 2010.
9. K. Jager, O. Isabella, A. H. M. Smets, R.A.C.M.M. Van Swaaij, and M. Zeman, Solar Energy – fundamentals, technology and systems, Delft University of Technology, 2014.
10. T. C. Kandpal and H.P. Garg, Financial Evaluation of Renewable Energy Technologies, McMillan India Ltd., 2013
11. Dr. Brijesh Tripathi, Dr. Manoj Kumar, Solar Energy From Cells To Grid, CSMFL Publications, 2018.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: 3 Questions from each unit, each carrying 3 marks 36 Marks

Part B/Question: 2 Questions from each unit, each carrying 8 marks 64 Marks

Ph.D. Course					21PH708T Time Series Analysis					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To introduce the concept of random variables, central limit theorem & correlogram.
- To introduce the various probability models for modelling time series.
- To introduce the methods of estimation of parameters and forecasting.
- To introduce the concept of Periodogram and Spectral Analysis.
- To introduce the methods of State Space Models and applications.
- To introduce the concept of Wavelets and Multivariate Analysis.

UNIT 1 Random variables, Time series & Probability Models	**13 Hrs.**
Review of Probability theory and random variables, joint distribution, central limit theorem, Introduction to Time series: trend, seasonality, the correlogram, properties. Probability models: stationarity, weak stationarity, send-order stationary process, properties of autocorrelation function, purely random process, random walk model, Moving average (MA) process, Autoregressive (AR) process, ARMA and ARIMA models.	
UNIT 2 Parameter estimation & Forecasting	**13 Hrs.**
Estimating the autocovariance and autocorrelation function, ergodicity, Estimation of Parameters by fitting to various Probability Models, Box-Jenkins, seasonal ARIMA models. Introduction to forecasting, forecasting in univariate processes, extrapolation of trend, simple exponential smoothing, Holt-Winters forecasting procedures, Box-Jenkins procedure, Other methods.	
UNIT 3 Spectral Analsysis and State-Space Models.	**10 Hrs**
Stationary processes in the frequency domain: The spectral density function, the periodogram, spectral analysis. State-space models: Dynamic linear models and the Kalman filter.	
UNIT 4 Wavelet transforms and Introduction to Multivariate Analysis	**10 Hrs.**
Introduction to Wavelets: Discrete wavelet transform, Haar and Daubechies wavelets, Coiflets, Applications to Physical Problems. Introduction to multivariate analysis: Principal Component Analysis, Factor Analysis, Applications to Physical Problems.	
Max. <40> Hrs.	

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Understand the concept of random variables, central limit theorem & correlogram..

CO2 – Understand the various probability models for modelling time series..

CO3 – Understand the methods of estimation of parameters and forecasting.

CO4 – Understand the concept of Periodogram and Spectral Analysis..

CO5 – Understand the the methods of State Space Models and applications..

CO6 – Understand the concept of Wavelets and Multivariate Analysis.

TEXT/REFERENCE BOOKS

1. Chris Chatfield, “The Analysis of Time Series: An Introduction”, 6th edition, Chapman and Hall / CRC, 2003.
2. William Wei, “Time Series Analysis: Univariate and Multivariate Methods”, 2nd edition, Pearson/Addison Wesley, 2006.

Ph.D. Course					21PH709T - Advanced Condensed Matter Physics		
Teaching Scheme					Examination Scheme		
L	T	P	C	Hrs/Week	Theory	Practical	Total

3. R. H. Shumway and D. S. Stoffer, “Time Series Analysis and Its Applications: With R Examples”, 2nd edition, , 2006.
4. James D. Hamilton, “Time Series Analysis”, Princeton, NJ: Princeton University.
5. James D. Hamilton, “Time Series Analysis”, Princeton, NJ: Princeton University Press, 1994.

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs**

Part A/Question: <Details> <> Marks

Part B/Question: <Details> <> Marks

					MS	ES	IA	LW	LE/Viva	Marks
3	**0**	**0**	**3**	**3**	**25**	**50**	**25**	**--**	**--**	**100**

COURSE OBJECTIVES

- To develop conceptual understanding of the fundamental principles of Solid state Physics.
- To illustrate the various models for analyzing different approaches for metals and semiconductors.
- To understand the transport properties of metals and parameters affecting it.
- To discuss types of magnetism and magnetic properties of materials and their applications.

UNIT I	**12 Hrs.**
Bonding in crystals: covalent, ionic, metallic, hydrogen bond, van der Waal's bond and the Madelung constant. Crystalline solids, unit cell, primitive cell, Bravais lattices, Miller indices, closed packed structures. Atomic radius, lattice constant and density. Connection between orbital symmetry and crystal structure. Scattering from periodic structures, reciprocal lattice, Brillouin Zones.	
UNIT II	**10 Hrs.**
Electronic band structure in solids, Electrons in periodic potentials, Bloch's Theorem, Kronig-Penney model, Nearly free electron model, Tight-binding model: density of states, examples of band structures. Fermi surfaces of metals and semiconductors.	
UNIT III	**12 Hrs.**
Transport properties: Motion of electrons in bands and the effective mass, currents in bands and holes, scattering of electrons in bands, Boltzman equation and relaxation time, electrical conductivity of metals, thermoelectric effects, the Wiedemann-Franz Law	
UNIT IV	**11 Hrs.**
Magnetism: Diamagnetism (including Landau diamagnetism) and Paramagnetism including van Vleck and Langevin paramagnetism), Exchange interaction of free electrons, Band model of Ferromagnetism, superexchange, double exchange, Hubbard model, Antiferromagnetism, Neel temperature, spin-waves, 2D electron gas in a magnetic field, Quantum Hall Effect. Landau levels. Degeneracy. Fractional quantum Hall effect.	
	Max. 45 Hrs.

COURSE OUTCOMES

After completion of this course students will be able to;

CO1: Relate structural parameters for better understanding of the solid state physics.
CO2: Illustrate various solid state models for materials.
CO3: Analyze the various properties of the metals and semiconductors.
CO4: Explain transport properties and dependent parameters for various metals.
CO5: Describe theory of magnetism and it’s types in the solid state materials.
CO6: Determine the magnetic properties and their applications.

TEXT/REFERENCE BOOK

1. O. Madelung: Introduction to Solid State Theory.
2. Ibach and Luth : Solid State Physics.
3. Ashcroft and Mermin : Solid State Physics.
4. Kittel : Introduction to Solid State Physics.
5. C. Kittel: Quantum Theory of Solid.

Ph.D. Course					21PH710T - Introduction to Density Functional Theory					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To develop basic understanding about the electronic structure along with various properties.
- To revise fundamentals of solid state physics and to describe various functional.
- To illustrate and discuss various theorems explaining core of DFT.
- To apply knowledge of functional for calculation of properties of the material.

UNIT I Overview of an electronic structure	**12 Hrs.**
Quantum theory and the origins of electronic structure, Emergence of quantitative calculations, The greatest challenge: electron correlation, Electronic ground state: bonding and characteristic structures, Elasticity: stress-strain relations, Phonons and displacive phase transitions, Thermal properties: solids, liquids, and phase diagrams, Nanomaterials: between molecules and condensed matter, Electronic excitations: bands and band gaps.	
UNIT II Solid State essentials	**10 Hrs.**
Basic equations for interacting electrons and nuclei, Coulomb interaction in condensed matter, Statistical mechanics and the density matrix, Exchange and correlation, Structures of crystals : lattice + basis, The reciprocal lattice and Brillouin zone, Excitations and the Bloch theorem, Point symmetries, Point symmetries, Density of states.	
UNIT III Density functional theory: foundations	**12 Hrs.**
Thomas-Fermi-Dirac approximation : example of a functional, The Hohenberg-Kohn theorems, Constrained search formulation of density functional theory, Extensions of Hohenberg-Kohn theorems, Intricacies of exact density functional theory,The Kohn--Sham ansatz, The Kohn-Sham variational equations, Exc Vxc, and the exchange-correlation hole,Other generalizations of the Kohn-Sham approach.	
UNIT IV Functional for exchange and correlation	**11 Hrs.**
The local spin density approximation (LSDA),Generalized-gradient approximations (GGAs), LDA and GGA expressions for the potential Vxc, Orbital-dependent functional 1: SIC and LDA + U, Hybrid functional Solving Kohn--Sham equations : Self-consistent coupled Kohn-Sham equations, Total energy functional , Achieving self-consistency , Force and stress .	
Max. 45 Hrs.	

COURSE OUTCOMES

After completion of this course students will be able to;

CO1: Enumerate the basic concepts of electronic structure of the materials. .

CO2: Illustrate various solid state concepts for materials.

CO3: Discuss various basic theorems for density functional theory.

CO4: Explain various functional and their co-relation with theorems.

CO5: Describe various approximations and potentials used in DFT.

CO6: Generalize the functional to solve Kohn-Sham equations.

TEXT/REFERENCE BOOK

1. Electronic structure: Basic Theory and Practical Methods, Richard Martin, Cambridge University Press
2. Density-Functional Theory of Atoms and Molecules; Robert G. Parr, Weitao Yang, Oxford University Press, (1989).
3. A Chemist's Guide to Density Functional Theory; Wolfram Koch, Max C. Holthausen, Wiley-VCH Verlag GmbH, (2001).