DEPARTMENT OF PHYSICS

ANNA UNIVERSITY, CHENNAI

VISION:

Department of Physics at Anna University shall strive towards the world class centre by producing students with higher technical knowledge, professional skills and other values. The Department shall provide an outstanding experience in teaching, research and consultancy. The Department shall perform frontier research and create knowledge base in pure and applied physics, materials science, laser engineering and areas of technological importance.

MISSION:

Department of Physics, Anna University shall provide high quality physics education, producing well prepared students who are intellectually and technically equipped in their abilities and understanding of physics and in particular materials science. The Department of Physics promotes high quality academic and research programmes and providing extension services in cutting edge technologies in materials science and laser engineering. The Department of Physics ensures the supportive campus climate in academic and research activities by meeting the need of the students, faculty and staff.

ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

M.PHIL. PHYSICS (FT)

REGULATIONS - 2019

CHOICE BASED CREDIT SYSTEM

1. PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

I. To provide training in Research Methodology as a pre Ph.D course.

II. To provide knowledge in advanced topics in Physics and in particular, Materials Science.

III. To provide specialized training and advanced knowledge in the field of interest.

IV. To provide training in undertaking project work, so as to analyze and solve the problem independently.

V. To provide training for making technical presentation and publishing results in any chosen topic related to the field of specialization.

2. PROGRAMME OUTCOMES (POs):

After going through one year of study, our M.Phil. (Physics) Graduates will exhibit ability to:

PO#	Graduate	Programme Outcome
1.	Research aptitude	An ability to independently carry out research /investigation and development work to solve practical problems
2.	Technical documentation	An ability to write and present a substantial technical report/document
3.	Technical competence	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
4.	Modern Tool Usage	Students will develop and demonstrate an ability to work in laboratory, conduct experiments, visualize data and interpret the results.
5.	Impact in society	Students will show the understanding of impact of materials in the society and also will be aware of contemporary issues.
6.	Life-long learning	Continue professional development and learning as a life-long activity.

3. PROGRAM SPECIFIC OUTCOMES (PSOs):

By the completion of M.Phil. (Physics) program the student will have following Program specific outcomes.

1. Motivated and trained to carryout research.
2. Trained to handle and analyze the research problems independently.
3. Trained to prepare project reports and research publications.
4. Acquire confidence for self-education and life-long learning.

4. PEO / PO Mapping:

PROGRAMME EDUCATIONAL OBJECTIVES	PROGRAMME OUTCOMES					
	PO1	PO2	PO3	PO4	PO5	PO6
I	✓	✓	✓	✓		
II	✓	✓	✓	✓		
III	✓	✓	✓	✓		
IV	✓	✓	✓	✓	✓	
V	✓	✓	✓	✓	✓	✓

Mapping of Course Outcome and Programme Outcome

		Course Name	PO01	PO02	PO03	PO04	PO05	PO06
YEAR 1	Semester 1	Research Methodology	✓	✓	✓	✓	✓	
		Advanced Materials Science	✓	✓	✓	✓	✓	
		Program Elective I (one from list of electives I)	✓	✓	✓	✓	✓	
		Seminar	✓	✓	✓	✓	✓	✓
	Semester 2	Program Elective II (one from list of electives II)	✓	✓	✓	✓	✓	
		Dissertation	✓	✓	✓	✓	✓	✓

ANNA UNIVERSITY, CHENNAI

UNIVERSITY DEPARTMENTS

M.PHIL. PHYSICS (FT)

REGULATIONS - 2019

CHOICE BASED CREDIT SYSTEM

CURRICULA AND SYLLABI

SEMESTER I

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PX5101	Research Methodology	FC	4	0	0	4	4
2.	PX5102	Advanced Materials Science	PCC	4	0	0	4	4
3.		Program Elective I	PEC	4	0	0	4	4
PRACTICAL								
4.	PX5111	Seminar	EEC	0	0	2	2	1
			TOTAL	**12**	**0**	**2**	**14**	**13**

SEMESTER II

S. NO.	COURSE CODE	COURSETITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Program Elective II	PEC	4	0	0	4	4
PRACTICAL								
2.	PX5211	Dissertation	EEC	0	0	32	32	16
			TOTAL	**4**	**0**	**32**	**36**	**20**

FOUNDATION COURSES (FC)

S. NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			Lecture	Tutorial	Practical		
1.	PX5101	Research Methodology	4	0	0	4	1
					Total Credits	4	

PROGRAM CORE COURSES (PCC)

S. NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			Lecture	Tutorial	Practical		
1.	PX5102	Advanced Materials Science	4	0	0	4	1
					Total Credits	4	

PROFESSIONAL ELECTIVE [PEC]

S.NO	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	GROUP
			Lecture	Tutorial	Practical		
1.	PX5001	Advanced Solid State Ionics	4	0	0	4	1
2.	PX5002	Advanced Solid State Theory	4	0	0	4	1
3.	PX5003	Advances in Crystal Growth and Characterization	4	0	0	4	1
4.	PX5004	Crystal Structure Analysis	4	0	0	4	1
5.	PX5005	Advanced Physical Metallurgy	4	0	0	4	1
6.	PX5006	Materials Characterization	4	0	0	4	1
7.	PX5007	Mechanical Behavior of Materials	4	0	0	4	1
8.	PX5008	Nanomaterials Characterization	4	0	0	4	1
9.	PX5009	Computational Materials Science	4	0	0	4	1
10.	PX5010	Condensed Matter Physics	4	0	0	4	1
11.	PX5011	Chaotronics	4	0	0	4	2
12.	PX5012	Physics of Nanodevices	4	0	0	4	2
13.	PX5013	High Pressure Physics	4	0	0	4	2
14.	PX5014	Advanced Nonlinear Optics	4	0	0	4	2
15.	PX5015	Laser Theory and Applications	4	0	0	4	2
16.	PX5016	Applied Computational Methods	4	0	0	4	2
17.	PX5017	Modern Energy Conversion Techniques.	4	0	0	4	2
18.	PX5018	Nonlinear Science: Solitons, Chaos and Fractals	4	0	0	4	2
19.	PX5019	Spectroscopic Techniques	4	0	0	4	2
20.	PX5020	Superconductivity and Applications	4	0	0	4	2

Attested

DIRECTOR
Centre for Academic Courses
Anna University, Chennai-600 025

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S. No	COURSE CODE	COURSE TITLE	PERIODS PER WEEK			CREDITS	SEMESTER
			Lecture	Tutorial	Practical		
1	PX5111	Seminar	0	0	2	1	1
2	PX5211	Dissertation	0	0	32	16	2
					Total Credits:	**17**	

SUMMARY

	M.PHIL. PHYSICS (FT)			
	Subject Area	Credits per Semester		**Credits Total**
		I	**II**	
1.	FC	4	0	**04**
2.	PCC	4	0	**04**
3.	PEC	4	4	**08**
4.	EEC	1	16	**17**
	Total Credit	**13**	**20**	**33**

PX5101 **RESEARCH METHODLOGY** **L T P C**
4 0 0 4

OBJECTIVES

- To introduce the students on objectives and various techniques of research.
- To equip students with research methodology essential for pursuing higher studies.
- To make the students to apply scientific tools, concepts and theories to solve scientific problems.
- To enable students in writing scientific research reports, thesis and dissertation.
- To introduce the concept of intellectual property rights and its protection.

UNIT I TECHNIQUES FOR RESEARCH 12

Research: Definition, characteristics, objectives, research and scientific method - Types of Research: Descriptive vs. analytical, fundamental vs. applied, quantitative vs. qualitative, conceptual vs. empirical - Methodology: Introduction, research process overview, formulating the research problem - defining the research problem - research questions. Literature review: Concepts and theories. Formulation of hypothesis: Sources, characteristics, role of hypothesis - Research design.

UNIT II EXPERIMENTAL DATA PROCESSING 12

Data collection techniques - concept of measurement - validity and reliability of measurement. Sampling: Statistical population, sampling frame, sampling error, sample size, simple random sample, systematic sample, practical considerations of sampling - models - reconstruction of input signals - preliminary processing of experimental data: filtering - quasi-real experiments - reconstructed signal accuracy.

UNIT III DATA ANALYSIS AND INTERPRETATION 12

Basic concepts and definitions on data and error - various types of data and their error – propagation of errors – four steps to a meaningful experimental results. Basic statistical concepts – best estimate of true value of data – measures of central tendency - measures of dispersion - measures of asymmetry - measures relationship. Significance test – chi square test for goodness of fit – criteria for goodness of fit. Curve fitting - best fit - least square regression - nonlinear regression - optimization. Visualization and presentation of data - univariate analysis.

UNIT IV TECHNIQUES OF RESEARCH WRITING AND PRESENTATION 12

Effective scientific writing: Definition, article writing, essay writing, research paper writing, preparation of research project, thesis writing , dissertation writing, book writing, book-review writing. Criteria for good research - ethical issues related to publishing, plagiarism and self-plagiarism - citation methods: foot note, text note, end note, bibliography - citation rules - presentation of seminar talk and viva-voce talk.

UNIT V INTELLECTUAL PROPERTY RIGHTS 12

An overview of Intellectual property (IP) – Importance – Protection of IPR – Patents – Patentable and Non-Patentable inventions – Procedure for filing of patents – acquisition of patent rights – patents offices in India and jurisdiction – Modification of granted patents – protection against unfair competition – Enforcement of IPR - New developments of IPR.

TOTAL : 60 PERIODS

OUTCOME

At the end of this course, the students will be able to

- Understand research problem formulation and analyze research related information
- Apply research design methodology
- Carryout systematic research experiments, data handling, interpretation and presentation.
- Follow research ethics.
- Appreciate the importance of IPR in research and development.

REFERENCES
1. Wayne Goddard and Stuart Melville. Research methodology: An introduction. JUTA & Co., Lansdowne, 2007.
2. C.R.Kothari and G. Garg. Research methodology: Methods and techniques. New Age International Publishers, 2019.
3. Ranjit Kumar. Research Methodology: A Step by Step Guide for beginners. SAGE Publications Ltd., 2014.
4. Robert P. Merges, Peter S. Menell and Mark A. Lemley. Intellectual Property in New Technological Age. Aspen Publishers, 2009.
5. B.Ramakrishna and H.S. Anil Kumar. Fundamentals of Intellectual Property Rights: For Students, Industrialist and Patent Lawyers. Notion Press, 2017.

PX5102 ADVANCED MATERIALS SCIENCE **L T P C**
4 0 0 4

OBJECTIVES
- To impart knowledge on optoelectronic materials
- To learn about ceramic processing and advanced ceramics
- To understand the processing and applications of polymeric materials
- To gain knowledge on the fabrication of composite materials
- To learn about shape memory alloys, metallic glasses and nanomaterials

UNIT I OPTOELECTRONIC MATERIALS 12
Importance of optical materials – properties: Band gap and lattice matching – optical absorption and emission – charge injection, quasi-Fermi levels and recombination – optical absorption, loss and gain. Optical processes in quantum structures: Inter-band and intra-band transitions Organic semiconductors. Light propagation in materials – Electro-optic effect and modulation, electro-absorption modulation – exciton quenching.

UNIT II CERAMIC MATERIALS 12
Ceramic processing: powder processing, milling and sintering – structural ceramics: zirconia, almina, silicon carbide, tungsten carbide – electronic ceramics – refractories – glass and glass ceramics.

UNIT III POLYMERIC MATERIALS 12
Polymers and copolymers – molecular weight measurement – synthesis: chain growth polymerization – polymerization techniques – glass transition temperature and its measurement – viscoelasticity – polymer processing techniques – applications: conducting polymers, biopolymers and high temperature polymers.

UNIT IV COMPOSITE MATERIALS 12
Particle reinforced composites – fiber reinforced composites – mechanical behavior – fabrication methods of polymer matrix composites and metal matrix composites – carbon/carbon composites: fabrication and applications.

UNIT V NEW MATERIALS 12
Shape memory alloys: mechanisms of one-way and two-way shape memory effect, reverse transformation, thermoelasticity and psuedoelasticity, examples and applications - bulk metallic glass: criteria for glass formation and stability, examples and mechanical behavior - nanomaterials: classification, size effect on structural and functional properties, processing and properties of nanocrystalline materials, single walled and multiwalled carbon nanotubes

TOTAL: 60 PERIODS

Attested

OUTCOMES

Upon completion of the course, the students will

- acquire knowledge on optoelectronic materials
- be able to prepare ceramic materials
- be able to understand the processing and applications of polymeric materials
- be aware of the fabrication of composite materials
- be knowledgeable of shape memory alloys, metallic glasses and nanomaterials

REFERENCES

1. Jasprit Singh, Electronic and optoelectronic properties of semiconductor structures, Cambridge University Press, 2007.
2. D.W.Richerson, Modern Ceramic Engineering: Properties, Processing, and Use in Design, Fourth Edition, CRC Press, 2018.
3. Joel R.Fried, Polymer Science and Technology, Pearson Prentice Hall, 2014.
4. D.Hull & T.W.Clyne, An introduction to composite materials, Cambridge University Press, 2008.
5. P.K.Mallick. Fiber-Reinforced Composites. CRC Press, 2008.
6. B.S.Murty, P.Shankar, B.Raj, B.B.Rath and J.Murday. Textbook of Nanoscience and Nanotechnology. Springer-Verlag, 2012.
7. K.Yamauchi, I.Ohkata, K.Tsuchiya and S.Miyazaki (Eds). Shape Memory and Superelastic Alloys: Technologies and Applications. Woodhead Publishing Limited, 2011.

PX5001	**ADVANCED SOLID STATE IONICS**	**L**	**T**	**P**	**C**
		4	**0**	**0**	**4**

OBJECTIVES

- To introduce the basic aspects of solid state physics.
- To impart knowledge on solid state Ionics, hydrogen storage and nano-ionic materials.
- To introduce the students to micro batteries, fuel cells, super capacitors and their applications.
- To familiarize the students to various characterization techniques for new cathode materials.
- To expose the students to the various application of ionic materials.

UNIT I INTRODUCTION 12

Types of ionic solids – fast ionic solids- point defect type – sub lattice type –fast ionic materials- Ionic and electronic conductors with ion transport – alkali metal ion conductors – silver ion conductors – cation conductors – oxygen ion conductors.

UNIT II SUPERIONIC MATERIALS AND STRUCTURES 12

Principles for high silver and copper ion conductors - proton conductors - Hydrogen storage materials – different methods of preparation of amorphous, poly- and single-crystalline materials – thermal evaporation – sputtering – CVD – gel dissociation – crystal growth technique.

UNIT III EXPERIMENTAL PROBES 12

Structural characterization - Thermodynamic properties - ion transport (macroscopic properties) - Ion dynamics (microscopic properties) - Phoelectron spectroscopy - EXAFS (extended X-ray absorption fine structure) - Local environment studies - FTIR, Thermal analysis - DTA - DSC - TG. - Particle size analysis - SEM-TEM-BET.

UNIT IV APPLICATION OF SUPER IONIC SOLIDS 12

Diffusion coefficient measurement in solids/liquids-sensor and partial pressure gauges - oxygen sensors (concentration cell type) - sulfur sensor (formation cell type) - Fuel cells - solid state battery - super capacitors.

UNIT V LITHIUM BATTERIES 12

Principles and general background of ambient temperature lithium batteries - synthesis of nano materials for lithium batteries - properties, structure and conductivity of organic and inorganic electrolytes for lithium battery systems - thin film deposition - pulsed laser deposition of electrodes - preparation and fabrication - characterization of Li-ion cells - Comparison of lead acid-NiCd and Li-ion batteries - Application of Lithium batteries in electronic devices and electric vehicle - Solar energy conversion devices.

TOTAL: 60 PERIODS

OUTCOMES

- The students would have learnt the basic aspects of solid state physics.
- Gained knowledge on solid state Ionics, hydrogen storage.
- Learnt about micro batteries, fuel cells, super capacitors.
- Learnt about the various characterization techniques available for cathode materials.
- The students are familiar with various applications of ionic materials.

REFERENCES

1. S.Chandra. Superionic solids:Principles and applications. North Holland Amsterdam, 1981.
2. H.V.Keer. Principles of solid state physics. Wiley Eastern Ltd., New Delhi, 1993.
3. D.S.Clive. Modern Battery Technology. Alean International Ltd, Banbury, Elis Horwood Publishers, 1991.
4. J.P.Gabano. Lithium batteries. Academic Press, London, 1983.
5. S.Selladurai. (Ed.). Solid State Ionic Device: Science & Technology. Allied Publishers, Chennai, 2000.
6. G.A.Ozin and C.Arsenault Andre. Nanochemistry, A chemical approach to nanomaterials. Springer, 2005.
7. A.R.West. Solid State Chemistry and its applications. Wiley, 2013.

PX5002 ADVANCED SOLID STATE THEORY

L	T	P	C
4	0	0	4

OBJECTIVES

- To introduce the basics of atomic molecular structure.
- To know about density functional theory.
- To make the students to understand the computational methods of band structure.
- To inspire the theoretical aspects of other band structure methods
- To progress the students with predicting properties of matter from electronic structure.

UNIT I ATOMIC MOLECULAR STRUCTURE 12

Central field approximation - Thomas Fermi model and its application - Hartree and Hartree Fock equations - hydrogen molecule - Heitler London model - hybridization.

UNIT II DENSITY FUNCTIONAL THEORY 12

Hohenberg-Kohn theorem - Kohn-Sham ansatz - approach to many-body problem using independent particle methods - solving Kohn-Sham equations - LDA - LSDA - GGA - nonlocal functionals.

UNIT III BAND STRUCTURE METHODS 12

The tight-binding method - linear combination of atomic orbitals - application to bands from *s*-levels general features of tight-binding levels - Wannier functions

UNIT IV OTHER BAND STRUCTURE METHODS 12

Independent electron approximation - general features of valence band wave functions - cellular method - muffin-tin potentials - augmented palne wave method - Green's function (KKR) method - orthogonalized plane wave method - pseudopotentials.

UNIT V PREDICTING PROPERTIES OF MATTER FROM ELECTRONIC STRUCTURE 12

Lattice dynamics from electronic structure theory - phonons and density response functions - periodic perturbations and phonon dispersive curves - dielectric response functions - effective charges - electron-phonon interactions and superconductivity - magnons and spin response functions.

TOTAL: 60 PERIODS

OUTCOMES

- The students will understand the basic concepts of atomic molecular structure.
- Keen knowledge in density functional theory.
- Crack the computational studies of band structure.
- Apply the theoretical aspects of other band structure methods.
- The students will able to understand on predicting properties of matter from electronic structure.

REFERENCES

1. Richard M.Martin. Electronic structure Basic theory and practical methods. Cambridge University press, 2004
2. N.W. Ashcroft and N.D.Mermin, Solid State Physics. Cengage Learning Asia, 2016.
3. H.L.Skriver, The LMTO method: Muffin-Tin Orbitals and Electronic Structure. Springier, 2011.
4. G.C.Fletcher. Electron theory of solids. North Holland Pub. Co. 1980.

PX5003 ADVANCES IN CRYSTAL GROWTH AND CHARACTERISATION

L	T	P	C
4	0	0	4

OBJECTIVES

- To make the students understand the theory of formation of nucleus.
- To understand the different theories involved in crystal growth.
- To expose the students to different methods of bulk crystal growth.
- To expose the students to different methods of thin and thick film growth technology.
- To make the students understand different characterization techniques to analyse bulk single crystal and thin films.

UNIT I NUCLEATION 12

Theory of nucleation – Gibbs-Thomson equation for vapour, melt and solution – energy of formation of a nucleus – different possible shapes of nucleus – Homogeneous nucleation of Binary system – Heterogeneous nucleation – cap shaped – disc shaped nucleus.

UNIT II CRYSTAL GROWTH THEORY 12

Surface energy theory – Diffusion theory – Adsorption layer theory – Volm1er theory – Bravais theory – Kossel theory – Stranski’s treatment. Bulk diffusion model – Physical modelling of BCF theory – BCF differential surface diffusion equation – Temkins model of crystal growth, PBC theory of crystal growth.

UNIT III BULK CRYSTAL GROWTH 12

Bridgman technique – Czochralski technique – Growth of III – V materials – Liquid Encapsulated Czochralski technique (LEC) – Growth of oxide materials – Solution growth – Low temperature solution growth – High temperature solution growth (flux growth), Hydrothermal method.

UNIT IV CRYSTAL GROWTH – FILMS AND EPITAXIAL LAYERS 12

Electrocrystallization – Liquid Phase Epitaxy (LPE) – Vapour Phase Epitaxy – Metal Organic Vapour Phase Epitaxy (MOVPE) – Molecular Beam Epitaxy (MBE) – Atomic Layer Epitaxy (ALE) – Chemical Beam Epitaxy (CBE).

UNIT V CHARACTERIZATION TECHNIQUES 12

Single crystal diffraction techniques – Powder diffraction – X- ray fluorescence - Electron Probe Micro Analysis – Secondary Ion Mass Spectroscopy (SIMS), Electron Spectroscopy for Chemical Analysis (ESCA)- Electrical conductivity – Measurement of dielectric constant – Microhardness – Etching studies.

TOTAL: 60 PERIODS

OUTCOMES

- Students will be able understand the basic theory of nucleus formation and types in it.
- It provides the knowledge on different theories involved in bulk crystal growth.
- It makes the students to understand the different methods of growing single crystals.
- It imparts the knowledge on different methods of thin and thick film growth technology.
- Students will be able to understand and learn how to analyze the grown bulk single crystal and thin films using different characterization techniques.

REFERENCES

1. Makoto Ohara and Robert C. Reid., Modelling crystal growth rates from solution. Prentice-Hall of India P.Ltd, New Delhi, 1973.
2. J.C. Brice, Crystal Growth Processes .John Wiley & Sons, New York, 1986.
3. B.R. Pamplin. Crystal Growth. Pergamon press, London, 1975.
4. X.F. Zong, Y.Y. Wang, Material and Process Characterization for VLSI J. Chen, World Scientific, New Jersey,1988.
5. Krishan Lal. Synthesis, Crystal Growth & Characterization. North-Holland, Amsterdam, 1982.
6. M.M.Faktor and I. Garret. Growth of crystals from vapour Chapman and Hall, London, 1974.
7. Siblia J.P. A guide to Materials Characterisation and chemical Analysis. VCH Publications, 1988.
8. P.Santhana Raghavan and P.Ramasamy, Crystal Growth Processes and Methods, KRU Publications, Kumbakonam, 2000.

PX5004 CRYSTAL STRUCTURE ANALYSIS

L	T	P	C
4	0	0	4

OBJECTIVES

- To teach the concept of crystal structures and symmetry, and diffraction theory
- To provide students with a background to X-ray generation, scattering theory and experimental diffraction from single crystals
- To provide instruction on the methods and basis for determining low-molecular weight crystal structures using X-ray Crystallography
- To give the students a background to the instrumentation used for powder diffraction and structure refinement using Rietveld method
- To teach the different levels of structure exhibited by proteins and nucleic acids and methods used in protein crystallography.

UNIT I SYMMETRY: LATTICE 12

Unit cell and Bravais lattices - crystal planes and directions - basic symmetry elements operations - translational symmetries - point groups - space groups - equivalent positions - Bragg's law - reciprocal lattice concept -Laue conditions - Ewald and limiting spheres - diffraction symmetry - Laue groups.

UNIT II DIFFRACTION 12

X-ray generation, properties - sealed tube, rotating anode, synchrotron radiation - absorption - filters and monochromators Atomic scattering factor - Fourier transformation and structure factor - anomalous dispersion - Laue, rotation/oscillation, moving film methods - interpretation of diffraction patterns - cell parameter determination - systematic absences - space group determination.

UNIT III STRUCTURE ANALYSIS 12

Single crystal diffractometers - geometries - scan modes - scintillation and area detectors - intensity data collection - data reduction - factors affecting X-ray intensities - temperature and scale factor - electron density - phase problem - normalised structure factor - direct method fundamentals and procedures -Patterson function and heavy atom method - structure refinement - least squares method - Fourier and difference Fourier synthesis - R factor - structure interpretation - geometric calculations - conformational studies - computer program packages.

UNIT IV POWDER METHODS 12

Fundamentals of powder diffraction - Debye Scherrer method - diffractometer geometries - use of monochromators and Soller silts - sample preparation and data collection - identification of unknowns - powder diffraction files (ICDD) - Rietveld refinement fundamentals - profile analysis - peak shapes - whole pattern fitting - structure refinement procedures - autoindexing - structure determination from powder data - new developments. Energy dispersive X-ray analysis - texture studies - crystallite size determination - residual stress analysis - high and low temperature and high pressure crystallography (basics only).

UNIT V PROTEIN CRYSTALLOGRAPHY 12

Globular and fibrous proteins, nucleic acids - primary, secondary, tertiary and quaternary structures - helical and sheet structures - Ramachandran map and its significance - crystallation methods for proteins - factors affecting protein crystallisation - heavy atom derivatives - methods used to solve protein structures - anomalous dispersion methods.

TOTAL: 60 PERIODS

OUTCOMES

Upon completion of the course the students will

- understand crystal symmetry and reciprocal lattice concept for X-ray diffraction
- gain a working knowledge of X-ray generation, X-ray photography with Laue, oscillation and moving film methods, and space group determination.
- get a working knowledge of single crystal diffractometers and single crystal structure determination using program packages
- understand the instrumentation used for powder diffraction, data collection, data interpretation, and structure refinement using Rietveld method
- get some insight into the structural aspects of proteins and nucleic acids, crystallization of proteins and methods to solve protein structures.

REFERENCES

1. Azaroff, L.V., "Elements of X-Ray Crystallography", Techbooksl, New York, 1992.
2. Blundell, T.L. and Johnson, L., "Protein Crystallography", Academic Press, New York, 1986.
3. Cullity, B.D. and Stock,S.R. "Elements of X-ray Diffraction", Pearson, 2014
4. Glusker, J.P. and Trueblood, K.N. Crystal Structure Analysis: A Primer", Oxford University Press, New York, 1994.
5. Ladd, M.F.C. and Palmer, R.A., "Structure Determination by X-ray Crystallography", Plenum Press, New York, 3rd Edition, 1993.
6. Stout, G.H. and Jensen, L."X-ray Structure Determination, A Practical Guide", Macmillan: New York, 1989.
7. Woolfson, M.M. "An Introduction to X-ray Crystallography" Cambridge University Press, New York, 1997.

PX5005	ADVANCED PHYSICAL METALLURGY	L T P C
		4 0 0 4

OBJECTIVES

- To study the characteristic properties of intermetallic alloys as well as compositional and surface morphology by various electro-magneto-optical instruments.
- To understand the phase diagrams of (two or more elements) alloys and their invariant reactions during solidification on cooling.

- To study the Fick's first and second law of diffusion and their applications
- To study some of mechanical properties such as stress-strain, creep, fatigue, hardness etc. of metals.
- To learn the high strength structural steels, tool steels and alloy steels for various engineering applications.

UNIT I STRUCTURE OF ALLOYS 12

Hume Rothery rules - Intermediate phases – Intermetallic compounds – Improvement in mechanical and electrical properties – metallography: Optical microscope – SEM – TEM – Determination of chemical composition – Electron probe microanalysis.-Structural stability of alloys-EXAFS measurements.

UNIT II PHASE DIAGRAMS 12

Free energy – Composition curves – Lever rule – Invariant reactions – Eutectic system – Property variations in eutectic systems –Peritectic and peritectoid systems- Non equilibrium solidification – Zone meting.

UNIT III DIFFUSION 12

Ficks laws – Mechanisms of diffusion – Solutions of diffusion equation – Kirkendal effect – Factors affecting diffusion – Applications of diffusion.

UNIT IV MECHANICAL PROPERTIES 12

Stress-strain curve – Compressibility – Plastic deformation mechanisms, Tensile strength – Creep – Fracture – Fatigue failures – Effect of grain size on mechanical properties-Hardness.

UNIT V ENGINEERING ALLOYS 12

Steels – High strength structural steels – tool materials – high temperature alloys – cast iron – light alloys – Al, Mg and Ti and their alloys – Copper based systems –brass and bronze.

TOTAL : 60 PERIODS

OUTCOMES

- Reveal's the basic properties of intermetallic phases and their compounds utilized for applications along with characteristic studies such as surface morphology and composition.
- The phase diagrams of binary or multi- component systems which under goes various invariant reactions will be discussed.
- The concept of time independent and dependent diffusion equations applied for surface treatment to improve hardness of tool components will be discussed.
- The various mechanical properties of metals such as tentile, creep, fatigue etc. with change in grain size will be discussed.
- The engineering alloy steels with various alloying elements that improve the strength even at high working temperature will be discussed.

REFERENCES

1. A.G.Guy and J.J.Hren. Physical Metallurgy, Oxford, IBH, 1980.
2. Raghavan.V., Physical Metallurgy, Prentice Hall, 1989.
3. Westbrook.J. (Ed.), Intermetallics, Academic Verlag, 1995.
4. Taylor. X-ray metallography, Mentice Hall, 1982.

PX5006 MATERIALS CHARACTERIZATON L T P C
4 0 0 4

OBJECTIVES

- To introduce to the students the important techniques used for materials characterization.
- To make the students learn some important thermal analysis techniques namely TGA, DTA, DSC and TMA.
- To make the students understand the theory of image formation in an optical microscope and to introduce other specialized microscopic techniques.

- To make the students learn and understand the principle of working of electron microscopes and scanning probe microscopes.
- To make the students understand some important electrical and optical characterization techniques for semiconducting materials.
- To introduce the students the basics of x-ray diffraction techniques and some important spectroscopic techniques.

UNIT I THERMAL ANALYSIS 12

Introduction – thermogravimetric analysis (TGA) – instrumentation – determination of weight loss and decomposition products – differential thermal analysis (DTA)- cooling curves - differential scanning calorimetry (DSC) – instrumentation – specific heat capacity measurements – determination of thermomechanical parameters .

UNIT II MICROSCOPIC METHODS 12

Optical Microscopy: optical microscopy techniques – Bright field optical microscopy – Dark field optical microscopy – Dispersion staining microscopy - phase contrast microscopy -differential interference contrast microscopy - fluorescence microscopy - confocal microscopy - - digital holographic microscopy - oil immersion objectives - quantitative metallography - image analyzer.

UNIT III ELECTRON MICROSCOPY AND SCANNING PROBE MICROSCOPY 12

SEM, EDAX, EPMA, TEM: working principle and Instrumentation – sample preparation – data
collection, processing and analysis- Scanning tunneling microscopy(STEM)- Atomic force microscopy(AFM) - Scanning new field optical microscopy.

UNIT IV ELECTRICAL METHODS AND OPTICAL CHARACTERISATION 12

Two probe and four probe methods- van der Pauw method – Hall probe and measurement – scattering mechanism – C-V characteristics – Schottky barrier capacitance – impurity concentration – electrochemical C-V profiling – limitations. Photoluminescence – light – matter interaction – instrumentation – electroluminescence – instrumentation – Applications.

UNIT V X-RAY AND SPECTROSCOPIC METHODS 12

Principles and instrumentation for UV-Vis-IR, FTIR spectroscopy, Raman spectroscopy, ESR, NMR,NQR, XPS, AES and SIMS-proton induced X-ray Emission spectroscopy (PIXE) –Rutherford Back Scattering (RBS) analysis-application - Powder diffraction - Powder diffractormeter - interpretation of diffraction patterns - indexing - phase identification - residual stress analysis - Particle size, texture studies - X-ray fluorescence spectroscopy - uses.

TOTAL: 60 PERIODS

OUTCOMES

- Students will be able to describe the TGA, DTA, DSC and TMA thermal analysis techniques and make interpretation of the results.
- Students have learned the concept of image formation in Optical microscope, developments in other specialized microscopes and their applications'
- Students have learned the working principle and operation of SEM, TEM, STM and AFM.
- Students have understood Hall measurement, four –probe resistivity measurement, C-V, I-V, Electrochemical, Photoluminescence and electroluminescence experimental techniques with necessary theory.
- Students have learned the theory and experimental procedure for x- ray diffraction and some important spectroscopic techniques and their applications.

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2. J.A.Belk. Electron microscopy and microanalysis of crystalline materials. Applied Science Publishers, London, 1979.
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4. D.Kealey and P.J.Haines. Analytical Chemistry. Viva Books Private Limited, New Delhi, 2002.

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PX5007 MECHANICAL BEHAVIOR OF MATERIALS

L	T	P	C
4	0	0	4

OBJECTIVES

- To introduce the various factors that affect the mechanical behavior of bulk materials.
- To make the students understand about the mechanical properties of thin films.
- To impart knowledge on mechanical properties of biomaterials and biocompatibility
- To make the students understand about nanomechanics.
- To expose the students to the various methods for characterizing the mechanical properties.

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UNIT I MECHANICAL PROPERTIES OF BULK MATERIALS 12

Mechanical properties of inorganic materials (metals, ceramics) and organic materials (polymers, fibres) and composites (material blends, nanocomposites, filled and reinforced systems). Mechanical testing, enthalpy elasticity, rubber elasticity, viscoelasticity, plasticity, viscoplasticity, fracture properties, deformation velocity and temperature influence. Molecular and morphological influence on the mechanical properties. External influence including moisture, solvents and oxidation. Introduction to the mechanical behavior of small scale components, structures and devices.

UNIT II MECHANICAL PROPERTIES OF THIN FILMS 12

Stresses in thin films -Measurement of stresses in thin films -Wafer curvature and Stoney equation - Stresses due to different deposition processes.

UNIT III MECHANICAL PROPERTIES OF BIOMATERIALS 12

Introduction to nanomechanics - Force versus distance curve - Single cell mechanics Qualitative introduction to intra - and intermolecular forces - Quantitative description of intra - and intermolecular forces - Molecule - surface interactions - Colloids and interparticle potentials - Van der Waals forces at work: Gecko feet adhesion - The electrical double layer (EDL) theory - Nanomechanics of cartilage - Protein - surface interactions - Nanomechanics and biocompatibility: Protein-biomaterial interactions.

UNIT IV MECHANICAL PROPERTIES OF NANOMATERIALS 12

Deformation behaviour of nanomaterials. – comparison of mechanical characterics in bulk and nano – Reason for change in characteristics - Fracture and creep - Nanomechanics and nanotribology.

UNIT V INSTRUMENTS FOR MEASUREMENT 12

Small scale mechanical characterization including: nanoindentation, thin film bulge test, and electron microscopy methods. Nanoindentation: Force control and displacement control – common sources of artifacts – Nanoindentation instrumentation - Atomistic theories of tip-sample interaction- Oliver-Pharr method – other techniques of Nanoindentation – Different types of Nanoindentation.

TOTAL: 60 PERIODS

OUTCOMES

- The students would gain knowledge on the various factors that affect the mechanical behavior of bulk materials.
- Understand the mechanical properties of thin films.
- Gained knowledge on mechanical properties of biomaterials and biocompatibility
- The students would be able to analyze about nanomechanics.
- Apply their knowledge gained on characterizing the mechanical properties.

REFERENCES

1. Nanoindentation, Anthony C. Fischer-Cripp, Springer-Verlag GmbH, 2002
2. Nanoindentation in Materials Science**,** Edited by Jiri Nemecek, ISBN 978-953-51-0802-3, InTech
   publishers, 2012
   3. Nanoindentation, 3rd Edition Fischer-Cripps Laboratories Pty Ltd.

Attested

4. Fundamentals of Nanoindentation and Nanotribology, Norbert Hubert (Editor), Materials Research Society, 2009, ISBN-10: 155899789X
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6. Nanoindentation in Materials Science" ed by Jiří Němeček, Publishers InTeOp, 2012, ISBN: 9535108023 9789535108023

PX5008 NANOMATERIALS CHARACTERIZATION **L T P C 4 0 0 4**

OBJECTIVES

- To expose the students with knowledge of understanding the X-Ray analysis and characterization of nanomaterials
- To understand the surface analytical tools for nanomaterials
- To know the electrical and optical spectroscopy
- To inculcate principles and characterization of electron microscopy
- To inspire the nano-imaging spectroscopy

UNIT I X-RAY ANALYSIS OF NANOMATERIALS 12

Powder X-ray diffraction – powder diffraction techniques - Debye-Scherrer technique – indexing the powder pattern – calculation of particle size using Scherer method – problems associated with Scherer method –Weber-Fechner method for particle size analysis - Selected area diffraction - Low angle scattering - High resolution X-ray diffractometer (two and four crystal).

UNIT II SURFACE ANALYTICAL TOOLS FOR NANO-MATERIALS 12

UV and X-ray photoelectron spectroscopy; Auger electron spectroscopy; low energy electron diffraction and reflection high energy electron diffraction - secondary ion mass spectrometry - Rutherford backscattering - Medium energy ion scattering- Electron energy loss spectroscopy (EELS) and high resolution EELS. X-ray Photoelectron Spectroscopy, Auger photoelectron Spectroscopy.

UNIT III NANOSCALE ELECTRICAL SPECTROSCOPY 12

I-V/C-V; Hall, quantum Hall effects; transient charge spectroscopy. Optical spectroscopy: micro Photoluminescence; Absorption Spectroscopy, Excitation Spectroscopy, micro Raman Spectroscopy; Time domain spectroscopy.

UNIT IV ELECTRON MICROSCOPY 12

Principle of SEM – EDAX analysis- standardization of elements - nanoSEM, basic principles-STM-STEM - sample preparation – nanoparticles – thin films - TEM - High resolution TEM .

UNIT V NANO-IMAGING SPECTROSCOPY 12

Basic principles - Scanning Tunneling Microscopy, Scanning Force Microscopy (SFM/AFM), and scanning holographic microscopy -image interpretations; Scanning Near Field Optical Microscopy and scanning ion conductance microscopy.

TOTAL: 60 PERIODS

OUTCOMES

- The students will gain knowledge on X-Ray diffraction and its techniques
- Apply the knowledge in surface analysis
- Gain the keen idea of electrical characterization
- Crack the electron microscopy and thin flims
- The students will able to understand scanning spectroscopy

REFERENCES

1. G. Gao. Nanostructures and Nanomaterials. Imperial College Press, London, 2006.
2. Y. Gogotsi. Nanomaterials Handbook. CRC Taylor and Francis, New York, 2006.

PX5009 COMPUTATIONAL MATERIALS SCIENCE

L	T	P	C
4	0	0	4

OBJECTIVES

- To introduce the students on objectives and various techniques of computational materials science.
- To equip students with Ab Initio techniques.
- To make the students to apply tight-binding formalism and methods to solve the Schrodinger equation for large systems.
- To enable students in learning empirical methods and coarse-graining
- To introduce the concept of Monte Carlo methods.

UNIT I AB- INITIO METHODS 12

Hartree-Fock (HF) and density functional approaches: Quantum mechanics of identical particles – virial theorem – HF approximation – Electron correlations beyond the HF approximation – Density functional theory (DFT). Explicit methods to calculate electronic structures.Perturbation and linear response.Ab Initio molecular dynamics – Beyond the Born – quasiparticle theory and Green's function methods.

UNIT II TIGHT-BINDING METHODS 12

Tight-binding formalism – methods to solve the Schrodinger equation for large systems – self-consistent tight-binding formalism – applications to fullerenes, silicon and transition-metal clusters.

UNIT III EMPIRICAL METHODS AND COARSE-GRAINING 12

Reduction to classical potentials: Polar systems, Van der Waals potential, potential for covalent bonds, embedded-atom potential. Cluster expansion: Lattice gas model, Connolly-Williams approximation. Potential renormalization: Two-step renormalization scheme , first step , second step, application to Si, application to FePt alloys.

UNIT IV MONTE CARLO METHODS 12

Basis of the Monte Carlo (MC) method: Stochastic processes, Markov process, ergodicity. Algorithms for MC simulation: random numbers, simple sampling technique, importance of sampling technique, dynamic models, applications in classical particles, percolation, polymer systems, spin systems, nucleation, crystal growth and fractal systems.

UNIT V QUANTUM MONTE CARLO METHODS 12

Variational MC method – diffusion MC method – path-integral MC method – quantum spin models – advanced quantum MC methods. Cellular automata: Basics of CA, CA in two dimensions – lattice-gas methods – relation to MC.

TOTAL : 60 PERIODS

OUTCOMES

At the end of this course, the students will be able to

- Ab Initio methods for materials science research.
- understand tight-binding approximation technique.
- know empirical methods and coarse graining technique.
- apply Monte Carlo methods for materials simulation
- Appreciate the importance of quantum Monte Carlo methods.

REFERENCES
1. K. Ohno, K.Esfarjani and Y. Kawazoe. Computational Materials Science: From Ab Initio to Monte Carlo methods. Springer, 2018.
2. June Gunn Lee. Computational Materials Science: An Introduction. CRC Press, 2018.
3. Richard Lesar. Introduction to Computational Materials Science: Fundamentals to applications. Cambridge University Press, 2013.
4. A.M. Ovrutsky, A.S.Prokhodaand and M.S.Rasshchupkyna. Computational Materials Science: Surfaces, interfaces, crystallization. Elsevier, 2014.
5. Lily Chen. Computational Materials Science. Willford Press, 2018.

PX5010	**CONDENSED MATTER PHYSICS**	**L**	**T**	**P**	**C**
		4	**0**	**0**	**4**

OBJECTIVES

- To introduce the students on objectives of chemical bonding.
- To make the students to learn Block theorem.
- To make the students to know Hartree-Fock and density functional theories.
- To enable students in learning the importance of vibrations in molecules and crystals.
- To introduce the concept of transport theory.

UNIT I CHEMICAL BONDING 12

The simplest example: H_2^+, the tight-binding approximation, hybridization and covalent bonding, effect of overlap, eigenvectors and population analysis, charge transfer and ionic bonding, Jellium model and metallic bonding, Van der Waals bonding, cohesive energy of a solid.

UNIT II BLOCH THEOREM AND BAND STRUCTURE METHODS 12

Plane wave and LCAO formulation of Bloch theorem, Pe- riodicity and gap openings, band structure methods, DOS, *k*-point sampling, thermodynamic properties of non-interacting Fermi systems.

UNIT III HARTREE, HARTREE-FOCK AND DENSITY FUNCTIONAL THEORIES 12

The variational approach, HF equations, Koopman theorem, ionization potential and electron affinity, chemical potential, chemical hardness and gap as derivatives of the total energy, shortcomings of HF, derivation of the exchange functional. variational formulation, LDA. Kinetic energy functionals, finite temperature generalization.

UNIT IV VIBRATIONS IN MOLECULES AND CRYSTALS 12

Classical and quantum treatment, dynamical matrix and phonon spectrum, ZPE, acoustic and optical modes, thermodynamic properties, long wavelength limit and elasticity theory.

UNIT V TRANSPORT THEORY 12

Dynamics of electrons, Boltzmann equation, application to electrons and phonons, relaxation time approximation (RTA) from Fermi’s Golden rule, Matthiessen’s rule, thermoelectric effects, Drude model of transport and Einstein relations.

TOTAL : 60 PERIODS

OUTCOMES

On successful completions of this course, the students should able to

- Recall and describe the aspect of chemical bonding
- Describe Bloch theorem.
- Understand Hartree-Fock and density functional theories.
- Appreciate the importance of vibrations in molecules and solids.
- Explain the concept of transport physics.

REFERENCES
1. Michael Marder, "Condensed matter physics", Wiley (2015)
2. Akira Isihara, "Condensed matter physics", Dover Publications, Inc. (2007)
3. P.M. Chaikin and T.C. Lubensky, "Principles of condensed matter physics", Cambridge University Press (2000).
4. R.Shankar,"Quantumfieldtheoryandcondensed matter", Cambridge University Press (2017)
5. M.L.Cohen and S.G. Louie, "Fundamentals of condensed matter physics", Cambridge University Press (2016).

PX5011	CHAOTRONICS	L T P C
		4 0 0 4

OBJECTIVES
- To provide knowledge on the concepts of linear and non linear circuits.
- To introduce the students on the aspects of bifurcation and chaos.
- To make the students to understand the design of discrete map chaos circuits.
- To make the students to study the dynamics of continuous type chaotic circuits.
- To aid the students to design and study higher order chaotic circuits.

UNIT I LINEAR AND NONLINEAR CIRCUITS 12
Linear circuit elements – nonlinear circuit elements – circuits with linear elements – circuits with nonlinear elements – LC, RLC and forced RLC circuits - importance of nonlinearity – low and higher order electronic circuits with nonlinearity – Op-amp: Mathematical operations.

UNIT II BIFURCATION AND CHAOS 12
Introduction – periodic, quasi-periodic and chaotic behaviours – types of bifurcations – routes to chaos– discrete and continuous dynamical systems – characterization of periodic and chaotic motions.

UNIT III DISCRETE MAP BASED CHAOTIC CIRCUITS 12
Introduction – logistic map dynamics – circuit realization of logistic map – cob-web diagrams – Poincare-map construction - bifurcation diagram circuits – Henon map circuit – phase-portrait.

UNIT IV CONTINUOUS TYPE CHAOTIC CIRCUITS 12
Introduction – autonomous chaotic circuits: Chua's diode, Chua's circuit, Chua's canonical circuit – Wien-bridge oscillator based chaotic circuit – Colpitts chaotic oscillator – negative resistance based chaotic circuits – LC oscillator based chaotic circuits. Non-autonomous chaotic circuits: RL-diode circuit, driven Chua's circuit - Murali-Lakshmanan-Chua (MLC) circuit, Lindberg-Murali-Tamasevicius (LMT) oscillator – stochastic resonance circuit. Analog simulation circuits: Duffing oscillator, van-der Pol oscillator – Lorenz system – Rossler system – Threshold-controller based circuits.

UNIT V HIGHER-ORDER CHAOTIC CIRCUITS 12
Introduction – simple hyper-chaotic circuits with LCR elements – negative resistance based hyper-chaotic circuits – delay-chaotic circuits: autonomous and non-autonomous versions. Power-electronic circuits – CNN based chaotic circuits.

TOTAL: 60 PERIODS

OUTCOMES
After completing this course, the students should be able to
- Understand the basics of linear and non linear circuits.
- Acquire knowledge on bifurcation and chaos in dynamical systems.
- Design discrete type chaos circuits.
- Design continuous type chaos circuits.
- Understand the design philosophy of higher order chaotic circuits.

Attested

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1. M. Lakshmanan and K. Murali. Chaotic oscillators: Controlling and synchronization. World
Scientific, Singapore, 1996.
2. M. Lakshmanan and S. Rajasekar. Nonlinear dynamics: Integrability, chaos and patterns.
Springer, Berlin, 2001.
3. S.H.Strogatz. Nonlinear dynamics and chaos. Addison-Wesley, Manchester, 1994.
4. L.O. Chua, C.A. Desoer and E.S. Kuh. Linear and nonlinear circuits. McGraw-Hill, Singapore 1987.
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6. M.A. van Wyk and W.H. Steeb. Chaos in electronics. Springer, Berlin, 1997.

PX5012	PHYSICS OF NANODEVICES	L	T	P	C
		4	0	0	4

OBJECTIVES

- To introduce the concepts of macroscopic current flow.
- To make the students to understand quantum current flow aspects.
- To make the students to understand the aspects of mesoscopic transport.
- To make the students to acquire quantum phenomena
- To introduce the student the functioning of different nanostructured devices.

UNIT I MACROSCOPIC CURRENT FLOW 12

The classical model (Drude) of electronic conduction and Ohm's law – quantum model of electronic conduction – nearly free electron model of conduction and band structure – effective mass – origin of electrical resistance – size effects on electrical resistance – derivation of new Ohm's law.

UNIT II QUANTUM CURRENT FLOW 12

Need of size shrinking of devices – point contacts: From mesoscopic to atomic – conductance from transmission – transmission probability and current flow in quantum structures: Transmission probability, single potential step, single potential barrier, double potential barrier – Ballistic and diffusive transport.

UNIT III MESOSCOPIC TRANSPORT 12

Botlzmann transport equation – resistivity of thin films and wires: surface scattering (general principles, 1D, 2D and 3D confinements) – resistivity of thin films and wires: Grain-boundary scattering – measurement of resistance of thin films

UNIT IV QUANTUM PHENOMENA 12

Particle in a infinite potential well – particle in a finite one-dimensional potential well – particle in an infinite circular box – harmonic oscillator. Density of states: Bulk materials, wells, wires and dots. Population of valence and conduction bands: Bulk materials, wells, wires and dots. Joint density of states of nanostructures.

UNIT V NANOSTRUCTRED DEVICES 12

Resonant tunnelling diodes – FETs – single electron transistor – potential effect transistors – LEDs and diode lasers – nano-electro-mechanical devices – quantum dot cellular automata structures – logic gates.

TOTAL: 60 PERIODS

OUTCOMES

After completing this course, the students should able to

- Understand the concepts of macroscopic current flow.
- Understand quantum current flow aspects.
- Understand the aspects of mesoscopic transport.
- Acquire knowledge on quantum phenomena
- Understand the functioning of different nanostructured devices.

REFERENCES

1. Colm Durkan. Current at the Nanoscale: An introduction to Nanoelectronics. Imperial College Press, 2007.
2. Supriyo Datta. Quantum transport: Atom to Transistor. Cambridge University Press, 2005.
3. V.V.Mitin, V.A. Kochelap and M.A. Stroscio. Introduction to Nanoelectronics. Cambridge University Press, 2008.
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5. Edward L. Wolf. Nanophysics and Nanotechnology: An introduction to modern concepts in nanoscience. Wiley-VCH, 2015.

PX5013	HIGH PRESSURE PHYSICS	L T P C
		4 0 0 4

OBJECTIVES

- To introduce the aspects of High pressure science and the technology
- To expertise the measurements of high pressure
- To familiarize high pressure devices for various properties and applications
- To inspire properties of high pressure andspectroscopy studies
- To insight mechanical properties under pressure

UNIT I GENERAL TECHNIQUES 12

Definition of pressure – Hydrostaticity – generation of static pressure, pressure units – piston cylinder
– Bridgmann Anvil – Multi anvil devices – Diamond anvil cell. Measurement of High Pressure Primary gauge – Secondary gauge – Thermocouple pressure gauge – Resistance gauge – fixed point pressure scale – Ruby fluorescence – Equation of state.

UNIT II HIGH PRESSURE DEVICES FOR VARIOUS APPLICATIONS 12

X – Ray diffraction, Neutron diffraction – Optical studies – Electrical studies – Magnetic studies – High and low temperature applications – Ultra high pressure anvil devices.

UNIT III HIGH PRESSURE PHYSICAL AND CHEMICAL PROPERTIES 12

PVT Relations in fluids – Properties of gases under pressure – Melting phenomena – viscosity – thermo emf – thermal conductivity. Electrical conductivity – phase transition phonons, superconductivity – Electronic structures of metals and semiconductors – NMR and magnetic properties. Liquid crystals – spectroscopic studies – Infra red, Raman, Optical absorption – EXAFS.

UNIT IV MECHANICAL PROPERTIES AND INDUSTRIAL APPLICATIONS 12

Elastic constants – Measurements – Mechanical properties – Tension and compression – Fatigue – creep – Hydrostatic extrution, material synthesis – superhard materials – Diamond – oxides and other compounds – water jet.

UNIT V DYNAMIC PRESSURES 12

Shock wave – generation – measurements - Effect of shock wave on metals – Applications of shock wave.

TOTAL: 60 PERIODS

Attested

OUTCOMES

- Establish the operation of anvil and Multi-anvil devices
- Crack the gauge operations
- Design various anvil device applications
- Apply ideas of Electronic structure of metals and semiconductors
- After completing this course the students will be able to understand the basic concepts of the high pressure and various technological applications of high pressure.

REFERENCES

1. W. Bridgmann, The Physics of High Pressure, G. Bell and Sons Ltd., London, 1931.
2. B Vodar and Ph. Marteam, High Pressure Science and Technology, Vol I and II Pergamon Press, Oxford, 1980.
3. H.LI. D. Pugh, Mechanical Behaviour of Materials under Pressure,Elsevier Publishing Co., Ltd., New York, 1970.
4. M. I. Eremets, High Pressure Experimental methods, Oxford University press, New York, 1976.

PX5014	ADVANCED NONLINEAR OPTICS	L	T	P	C
		4	0	0	4

OBJECTIVES

- To educate the students about the importance of nonlinear optics.
- To inculcate the student to gain knowledge in understanding the concepts of second harmonic generation and parametric oscillation.
- To introduce the students the phenomena of third order nonlinearities.
- To study in detail the electro optic and photorefractive effects.
- To study the basic physics and applications of stimulated Raman scattering.

UNIT I ORIGIN OF OPTICAL NONLINEARITIES 12

Effects due to quadratic and cubic polarization – Response functions – Susceptibility tensors – Linear, second order and n^{th} order susceptibilities – Wave propagation in isotropic and crystalline media – The index ellipsoid.

UNIT II SECOND HARMONIC GENERATION (SHG) AND PARAMETRIC OSCILLATION 12

Optical SHG – Phase Matching – Experimental verification – Parametric oscillation – Frequency tuning– Power output and pump saturation – Frequency up conversion – Materials.

UNIT III THIRD ORDER NONLINEARITIES 12

Intensity dependent refractive index – Nonlinearities due to molecular orientation – Self-focusing of light and other self-action effects - Optical phase conjugation – Optical bistability and switching - Pulse propagation and temporal solitons.

UNIT IV ELECTRO –OPTIC AND PHOTOREFRACTIVE EFFECTS 12

Electro-optic effects – Electro-optic modulators - Photorefractive effect - Two beam coupling in Photorefractive materials – Four wave mixing in Photorefractive materials.

UNIT V STIMULATED SCATTERING PROCESSES 12

Stimulated scattering processes – Stimulated Brillouin scattering – Phase conjugation – Spontaneous Raman effect – Stimulated Raman Scattering – Stokes – Anti-Stokes Coupling in SRS – Stimulated Rayleigh - Wing Scattering.

TOTAL: 60 PERIODS

OUTCOMES

- The students will understand how the nonlinear effects affect the properties and dynamics of light-matter interaction.
- The students will gain knowledge in the field of second harmonic generation and parametric oscillation.
- The students will be introduced to the theory and applications of third order nonlinearities.
- The students will understand easily the physical principles of planar wave guides.
- The students will learn about stimulated Raman scattering and its applications.

REFERENCES

1. Robert W. Boyd. Non-linear Optics. Academic Press, London, 1992.
2. A.Yariv. Opto Electronics. John Wiley and Sons, New York, 1990.
3. P.N.Butcher and D.Cotter. The Elements of Nonlinear Optics. Cambridge Univ. Press, New York, 1990.
4. Y.V.G.S.Murti and C.Vijayan. Essentials of Nonlinear Optics. Wiley, 2014.

PX5015	LASER THEORY AND APPLICATIONS	L	T	P	C
		4	0	0	4

OBJECTIVES

- To learn about the fundamentals of Laser Theory and its process dynamics
- To learn about the different types of laser resonators and switching theory
- To learn about the different types of Gas lasers, configurations and liquid lasers
- To learn about the high power solid state lasers and semi conductor lasers
- To learn about Speckle and Holographic applications, Material processing applications and Medical applications

UNIT I LASER THEORY 12

Absorption - Spontaneous and stimulated emission - Einstein's coefficients - threshold conditions for laser action - Line broadening, Mechanism - Lorentzian and Doppler line shapes - Small signal gain - Gain coefficient - gain saturation - Rate equations for 3 and 4 level systems - Pulsed and CW lasers.

UNIT II RESONATORS AND SWITCHING THEORY 12

Resonant cavity - Fox and Li - Boyd and Gorden's theory on resonators - modes - Spot size - Types of resonators - Mode selection - Q switching theory and technique - Mode locking theory and technique.

UNIT III GAS AND LIQUID LASERS 12

Lasers: He-Ne, Argon Ion, Carbon dioxide, Nitrogen - Metal vapour - Gas dynamics - Excimer - Free electron lasers - Dye lasers organic dyes - Threshold conditions - Pumping configurations.

UNIT IV SOLID STATE AND SEMICONDUCTOR LASERS 12

Lasers: Ruby, Nd: YAG, Nd: Glass, Ti-sapphire, Alexandrite, lasers - Semiconductor lasers - Homo function - Hetro function - Quantum well laser.

UNIT V APPLICATIONS 12

Speckle, speckle interferometry - Holography - Holographic interferometry - Material processing - Surface treatment - welding, drilling and cutting - Laser ranging - Laser Doppler Velocimetry - Pollution monitoring - Medical and communication applications.

TOTAL: 60 PERIODS

Attested

OUTCOMES

- Students would gain knowledge on the fundamentals of Laser theory and its process dynamics
- Students would gain knowledge on the different types of laser resonators and switching applications
- Students would gain knowledge on the different types of configurations used in Gas lasers and liquid lasers
- Students would gain knowledge on the high power solid state lasers and semi conductor lasers
- Students would gain knowledge on the various types of laser applications

REFERENCES

1. William T. Silfvast. Laser Fundamentals. Cambridge University Press, 1999.
2. Oshea, Callen and Rhcdes. An Introduction to Lasers and their Applications. Addison Wesley, 1985.
3. A.Yariv. Quantum Electronics. Addison-Wesley, 1990.
4. Hariharan. Optical Holography. Academic Press, New York, 1983.
5. R.K.Erf.. Speckle Metrology. Academic Press, New York, 1978.

PX5016	APPLIED COMPUTATIONAL METHODS	L	T	P	C
		4	0	0	4

OBJECTIVES

- To introduce the concepts of probability, statistics and random numbers.
- To make the students to understand numerical interpolation, differentiation and integraton.
- To elucidate the solving methods of differential equations
- To introduce the concepts of empirical laws and curve fitting
- To make the students to understand Monte Carlo methods.

UNIT I BASIC PROBABILITY, STATISTICS AND RANDOM NUMBERS 12

Sampling – sample space – probability – probability distribution – Poisson distribution – Binomial distribution – frequency – mean – median – mode – standard deviation – moment correlation. Random numbers – generation of pseudo random numbers – Types of random number generators.

UNIT II NUMERICAL INTERPOLATION, DIFFERENTIATION AND INTEGRATION 12

Newton's forward and backward interpolation formulae - Lagrange's interpolation formula forunequal intervals - Error in polynomial interpolation and Newton's interpolation formula - Numerical differentiation - Maximum and minimum of a tabulated function – Numericalintegration - Trapezoidal rule - Romberg's method- Simpson's rule - Practical applications ofSimpson's rule.

UNIT III NUMERICAL SOLUTION OF ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS 12

Solution by Taylor's series - Euler's method - Runge-Kutta method - Predictor – Correctormethod - Milne's method - Adam Baschforth method - Numerical solution of partial differential equations - Finite equations - Elliptic equations - Laplace equation - Poisson's equation - Parabolic equations - Hyperbolic equations.

UNIT IV EMPRICAL LAWS AND CURVE FITTING 12

Linear law and laws reducible to linear law - Graphical method - method of group averages - principle of least squares - Fitting of straight line and parabola.

UNIT V MONTE CARLO METHODS 12

Monte Carlo (MC) optimization – Hit and miss method – Evaluation of value of Pi – MC integration – advantages and disadvantages of MC integration – sampling – random walk – Markov chain – metropolis algorithm – variational MC – diffusion MC – evaluation of ground state energy of Helium using variational MC.

TOTAL: 60 PERIODS

OUTCOMES

After completing this course, the students should able to

- understand probability, statistics and random numbers.
- understand numerical interpolation, differentiation and integraton.
- Solve differential equations
- use curve fitting methods.
- Understand Monte Carlo methods.

REFERENCES

1. T. Veerarajan. Probability, Statistical and Random Processes. Tata-McGraw Hill, 2008.
2. K.P.N.Murthy. Monte Carlo Methods in Statistical Physics. University Press, 2003.
3. Curtis F. Gerald. Applied Numerical Analysis. Pearson Education, 2004.
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5. Richard L. Burden, J.D.Faires and A.M. Burden. Numerical Analysis. Cengage Learning, 2015.

PX5017	MODERN ENERGY CONVERSION TECHNIQUES	L	T	P	C
		4	0	0	4

OBJECTIVES

- To introduce the alternative energy sources and utilization**.**
- To impart knowledge on the fundamentals of electrochemistry and electrode kinetics.
- To introduce the students to hydrogen as a renewable energy source.
- To familiarize the students to various batteries and super capacitors.
- To expose the students to biomass utilization and nuclear energy.

UNIT I INTRODUCTION TO ALTERNATIVE ENERGY SOURCES AND UTILIZATION 12

Principles of energy conversion: thermodynamic first and second laws, energy balances - Solar energy: Solar intensity and spectrum, global solar energy potential and current level of utilization, Photovoltaic - history, principles and theoretical limits. Solar cells – Batteries – Hydrogen storage materials – wind energy – Geothermal energy – Power from Water - Biomass - thermal power plants – Economy on energy projects – Utilizations.

UNIT II FUNDAMENTALS OF ELECTROCHEMISTRY AND ELECTRODE KINETICS 12

Introduction to Electrochemistry - Charge transfer reaction and reaction kinetics – Interface – Defects chemistry – Electrocatalysis – Electrochemical Reactors – Cell – Configuations and classifications - Electrode Processes – Potential and thermodynamics of a Cell – Electroactive layers – modified electrodes - Cell stack and thermal management.

UNIT III HYDROGEN AS A RENEWABLE ENERGY SOURCE 12

Fuel cell – Principle of working, construction - Characteristics and Classifications of Fuel Cells – Hybrid Fuel Cells – Electrical Vehicles – applications. Hydrogen Production: Direct electrolysis of water, thermal decomposition of water, biological and biochemical methods of hydrogen production- Storage of Hydrogen: Gaseous, Cryogenic and Metal hydride- Environmental impact.

UNIT IV BATTERIES AND SUPER CAPACITORS 12

Introduction to Primary and Secondary batteries- Principle- Battery materials - anode, cathode and electrolyte materials - Concepts of Rechargeable batteries – Applications of Lithium batteries, Lithium ion and polymer batteries. –- Super-capacitors: principles and working, electrode materials synthesis process, fabrication of the devices and their applications.

UNIT V BIOMASS UTILIZATION AND NUCLEAR ENERGY 12

Biodiesel and ethanol, Biomass utilization, Nuclear Energy: Potential of Nuclear Energy, International Nuclear Energy Policies and Regulations. Nuclear Energy Technologies – Fuel enrichment, Different Types of Nuclear Reactors, Nuclear Waste Disposal, and Nuclear Fusion.

TOTAL: 60 PERIODS

OUTCOMES

- The students would have learnt the basic aspects of alternative energy sources and utilization..
- Gained knowledge on the fundamentals of electrochemistry and electrode kinetics.
- Learnt about hydrogen as a renewable energy source..
- The students acquired knowledge about the various batteries and super capacitors.
- The students are familiar with various biomass utilization and nuclear energy.

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6. Allen J. Bard, Larry R. Fauliener. Electrochemical Methods – Fundamental and Applications. John Wiley & Sons, Inc. 2000.
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PX5018	**NONLINEAR SCIENCE: SOLITONS , CHAOS AND FRACTALS**	**L**	**T**	**P**	**C**
		4	**0**	**0**	**4**

OBJECTIVES

- To school the students about the analytical and numerical techniques of nonlinear dynamics.
- To make the students understand the concepts of various coherent structures.
- To train the students on bifurcations and onset of chaos.
- To educate the students about the theory of chaos and its characterization.
- To make the students aware of the applications of solitons, chaos and fractals.

UNIT I GENERAL **12**

Linear waves-ordinary differential equations(ODEs)-Partial differential equations(PDEs)- Methods to solve ODEs and PDEs.- Numerical methods – Linear and Nonlinear oscillators-Nonlinear waves-Qqualitative features.

UNIT II COHERENT STRUCTURES **12**

Linear and Nonlinear dispersive waves - Solitons – KdB equation – Basic theory of KdB equation – Ubiquitous soliton equations – AKNS Method, Backlund transformation, Hirota bilinearization method, Painleve analysis - Perturbation methods- Solitons in Optical fibres - Applications.

UNIT III BIFURCATIONS AND ONSET OF CHAOS **12**

One dimensional flows – Two dimensional flows – Phase plane – Limit cycles – Simple bifurcations – Discrete Dinamical system – Strange attractors – Routes to chaos.

UNIT IV CHAOS THEORY AND CHARACTERISTION **12**

One dimensional maps – Duffing oscillators – Lorenz equations – BVP and DVP oscillators – Pendulum – Chaos in nonlinear circuits – Chaos in conservative system – characterization of chaos – Fractals.

UNIT V APPLICATIONS 12

Soliton based communication systems – Solition based computation – Synchronization of chaos – Chaos based communication – Cryptography – Image processing – Stochastic – Resonance – Chaos based computation – Time Series analysis.

TOTAL: 60 PERIODS

OUTCOMES

- Students will gain knowledge about the available analytical and numerical methods to solve various nonlinear systems.
- The students will understand the concepts of different types of coherent structures and their importance in science and technology.
- The students will learn about simple and complex bifurcations and the routes to chaos.
- The students will acquire knowledge about various oscillators, characterization of chaos and fractals.
- The students will be well trained in the applications of solutions in telecommunication, applications of chaos in cryptography, computations and that of fractals.

REFERENCES

1. M.Lakshmanan and S.Rajasekar, Nonlinear Dynamics: Integrability, Chaos and Patterns. Springer, 2003.
2. A.Hasegawa and Y.Kodama, Solitons in Optical Communications. Oxford Press, 1995.
3. G.Drazin and R.S.Johnson. Solitons: An Introduction. Cambridge University Press, 1989.
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PX5019 SPECTROSCOPIC TECHNIQUES

L	T	P	C
4	0	0	4

OBJECTIVES

- To introduce students the fundamentals of infrared spectroscopy.
- To make the students understand about the Raman spectroscopy.
- To impart knowledge on SEM –EDX and FT-IR microscopy.
- To make the students understand about NMR – ESR spectroscopy.
- To expose the students to the NQR and Mossbauer spectoscopy

UNIT I INFRARED SPECTROSCOPY 12

Electromagnetic spectrum – absorption and emission spectra - Vibrational study of diatomic molecules – IR rotation – Vibrational spectra of gaseous diatomic molecules – simple gaseous polyatomic molecules – vibrational frequencies and qualitative analysis – Quantitative IR analysis – determination of bond length and bond moment – determination of interstellar atoms and molecules – IR spectrometer – elementary ideas of FT-IR.

UNIT II RAMAN SPECTROSCOPY 12

Raman effect – Raman shift – definition – observation of Raman spectra – Raman spectrometer – Quantum theory of Raman effect – probability of energy transition in Raman effect – Vibrational Raman spectra – structure determination from Raman and IR spectroscopy – SERS-Instrumentation and sampling Techniques – Non Linear Raman effects: inverse Raman effect – CARS – Applications.

UNIT III SEM –EDX AND FT-IR MICROSPECTROSCOPY 12

SEM imaging process: Scanning action – image construction (mapping) – magnification – Picture Element – Depth of Field – Image distortion.-Specimen preparation for SEM: Soils and Clays – polymers. EDX principle and application - Origin of FT-IR Micro spectroscopy -Basic principle-Schematic diagram and Working of FT-IR microspectrometer- Applications (Polymer science, Drug delivery system and Living cells)-Limitations

UNIT IV NMR and ESR SPECTROSCOPY 12

Origin of electron spin resonance and resonance condition – quantum mechanical theory of ESR – design of ESR spectrometer – Hyperfine structure study – ESR study of anisotropic systems – Triplet states study of ESR – application of ESR to transition metal ions – ENDOR.

UNIT V NQR AND MOSSBAUER SPECTROSCOPY 12

General principles of NQR – energy levels of quadruple transitions for half-integral spins – design of NQR Spectrometer – Application of NQR (Molecular Structure). Principle of Mossbauer Effect – Schematic arrangement of Mossbauer spectrometer – Isomer shift – Quadruple interaction – magnetic hyperfine interactions – applications of Mossbauer spectroscopy (Biological applications)

TOTAL: 60 PERIODS

OUTCOMES

- The students would gain knowledge on the infrared spectroscopy.
- Understand the experimental aspects of Raman spectroscopy.
- Gained knowledge on SEM –EDX and FT-IR microscopy.
- The students would be able to analyze about NMR – ESR spectroscopy.
- Apply their knowledge gained on characterizing the materials properties by using NQR and Mossbauer spectroscopy.

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3. G.Aruldhas. Molecular Structure and Spectroscopy. Prentice-Hall of India, 2005.
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PX5020	SUPERCONDUCTIVITY AND ITS APPLICATIONS	L	T	P	C
		4	0	0	4

OBJECTIVES

- To introduce the basic experimental aspects of the superconductivity
- To know about superconducting materials and its alloys
- To make the students to understand the experimental studies of superconducting materials
- To inspire the theoretical aspects of superconductivity
- To progress the students with various application in superconductivity

UNIT I BASIC EXPERIMENTAL ASPECTS 12

Zero electrical resistance – Meissner effect – A C diamagnetic susceptibility – heat capacity – optical absorption by superconductor – entropy change –thermal conductivity – destruction of superconductivity by external magnetic fields – type I and type II materials – superconducting behaviour under high pressures –flux quantisation – normal and Josephson tunneling.

UNIT II SUPERCONDUCTING MATERIALS 12

Elemental superconductors – superconducting compounds and its alloys – A15 compounds – chevral phase compounds

UNIT III HIGH TEMPERATURE SUPERCONDUCTORS 12

La-Ba-Cu-O, Y-Ba-cu-O, Bi-Sr-Ca-Cu-O and new systems and their crystal structures – Experimental studies on the new materials – organic superconductors –fullerenes.

UNIT IV THEORETICAL ASPECTS 12

Isotope effect – BCS theory – Role of electrons and phonons – applications of electron band structure results to calculate electron – Phonon coupling constant, McMillan's formula – GLAG theory – recent theories on high Tc materials, Coherence length, expression for critical temperature Tc, critical field Hc, critical current Jc – heavy fermion superconductivity.

UNIT V APPLICATIONS 12

Superconducting magnets – power generators, motors, transformers, power storage, power transmission – Josephson junction devices – IR sensors – SQUIDS –SLUGS – magnetically leviated trains – computer storage elements.

TOTAL: 60 PERIODS

OUTCOMESS

- The students will understand the basic concepts of superconductivity
- Keen knowledge in superconducting materials.
- Crack the experimental studies of superconducting materials
- Apply the theoretical aspects of superconductivity
- The students will able to understand various technological application of the superconductivity

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