Specialization: Advanced Condensed matter Physics

Semester-III	
Course Code	**Course Name**
21MSP608T	Advanced Condensed matter Physics
21MSP609T	Computational Techniques for Solid State Physicist
21MSP610T	Characterization Techniques
21MSP621P	Advanced Condensed matter Physics Laboratory
21MSP601	Project-I
	Semester-IV
	Project - II

M.Sc. Course					21MSP608T- ADVANCED CONDENSED MATTER 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 introduce the basic theoretical concepts of the condensed matter physics.
- To familiarise the students with the various aspects of the interactions effects.
- To bridge the gap between basic solid state physics and quantum theory of solids.
- To solve the problems related to metal-insulator transition and superconductivity.

UNIT 1 THEORETICAL MODELS AND APPROXIMATIONS	10 Hrs.
Semiclassical model of electron dynamics, Sources of electron scattering, Scattering probablity and relaxation times, Scattering at defects, scattering by phonons, Normal and Umklapp processes, Temeprature dependence of electrical conductivity of metals, Mathiessesn's rules, Bloch electrons in a uniform magnetic field, cyclotron resoance, Landau levels, density of states in magnetic field, De-Haas van Alfen effect, Measurement of Fermi surface.	
UNIT 2 DIELECTRICS AND LATTICE VIBRATIONS	**11 Hrs.**
Dielectric function of electron systems, screening, random phase approximation, plasma oscillations, optical properties of metals and insulators, excitons, polarons, fluctuation-dissipation theorem. Review of harmonic theory of lattice vibrations, anharmonic effects, electron-phonon interaction - mass renormalization, effective interaction between electrons and polarons.	
UNIT 3 METAL INSULATOR TRANSITION	**11 Hrs.**
Strongly interacting electrons in transition metal and rare earth compounds, Metal-Insulator transition, Mott insulators, Hubbard model, spin and charge density waves, electrons in a magnetic field, Landau levels, integer quantum Hall effect.	
UNIT 4 SUPERCONDUCTIVITY	**13 Hrs.**
Superconductivity phenomenon, Cooper instability, BCS theory, Ginzburg-Landau theory, Review of basic postulates of superconductivity, High temperature supercondtivity, Josephson junctions, SQUID magnetometer, recent advances in superconductors: MgB_2, Fe-based superconductors.	
	Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Understand sources of electron scattering during transport.

CO2 – Explain the temperature dependence of electrical conductivity of metals.

CO3 – Analyse lattice vibrations and interaction between electrons and polarons.

CO4 – Explain the basic operating mechanism quantum phenomenon in the insulators including quantum Hall effect.

CO5 – Apply the knowledge of superconductivity towards development of high temperature superconductors.

CO6 – Application of SQUID magnetometer to measure extremely subtle magnetic fields.

TEXT/REFERENCE BOOKS

1. Solid State Physics by N. W. Ashcroft and N. D. Mermin. (Publisher - Holt, Rinehart and Winston, 1976).
2. Quantum Theory of Solids by C. Kittel.(Wiley, 1987).
3. Condensed Matter Physics by M. P. Marder. (John Wiley & Sons, 2010).
4. Solid State Physics by H. Ibach and H. Luth. (Springer Science & Business Media, 2009).
5. Theoretical Solid State Physics by W. Jones and N. H. March.(Courier Corporation, 1985).
6. Many Particle Physics by G. D. Mahan. (Springer Science & Business Media, 2000).
7. Quantum Theory of solid State: Callaway.
8. Introduction to Magnetic Materials: B. D. Cullity
9. Magnetic Materials: Fundamentals and Device Applications : Nicola A. Spaldin

M.Sc.					21MSP609T- Computational Techniques for Solid State Physicist					
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 acquire the basic knowledge of integral and differential equations.
- To enable the students to apply the understanding of Schrodinger equation to construct density functional theory.
- To enable the students to understand the various dynamics of molecules and apply them for practical applications.
- To provide an understanding of the formalism Monte Carlo method with various ensembles.

UNIT 1 Integral and Differential Equations	08 Hrs.
Integral equations: calculation of scattering cross section (quantum scattering with a spherically symmetric potential) , Ordinary differential equations: classical electrons in crossed electric and magnetic fields, Partial differential equations: Laplace's equation, wave equations, diffusion equation and Maxwell's equations	
UNIT 2 Schrodinger Equation and Introduction to DFT	**08 Hrs.**
Solution of the generalized eigenvalue problem, perturbation theory and solution of Schrödinger equation for electrons in atoms by Hartree-Fock, Slater approximation, Born-Oppenheimer approximation, self-consistent procedure, first principles method, introduction to density functional theory (DFT), Hohenberg-Kohn theorems, Kohn-Sham approach, exchange correlation functional: LDA and GGA, other XC functional.	
UNIT 3 Molecular Dynamics Simulation	**12 Hrs.**
Integration methods, molecular dynamics simulations, classical and tight binding molecular dynamics, Langevin dynamics simulations for Brownian motion, simulations of planetary motion, oscillatory motion, chaotic motion, quantum molecular dynamics for hydrogen molecule.	
UNIT 4 The Monte Carlo Method	**12 Hrs.**
Monte Carlo simulations with various ensembles (random number generations), estimation of energy and chemical potential, Ising model, quantum Monte Carlo, genetic algorithms, transfer matrix methods for spin chains, finite element method for partial differential equations.	
Max 40 Hrs	

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - to grasp the concepts of various techniques to solve integral and differential equations.
CO2 - to reconcile the basics of Schrodinger equation and develop various approximation schemes.
CO3 - to demonstrate an ability to understand density functional theory.
CO4 - to categorize various kind of molecular dynamics.
CO5 - to analyze various types of motion using MD simulations.
CO6 - to explain and generalize Monte carlo method for various application.

TEXT/REFERENCE BOOKS

1. J.M. Thijssen, Computational Physics, Cambridge University Press, 2007.
2. N.J. Giordano, Computational Physics, Prentice-Hall, Upper Saddle River NJ, 1997.
3. D. Frenkel and B. Smith, Understanding Molecular Simulations, Academic Press, 2002.

4. J.G. Lee, Computational Materials Science, 2nd Ed., CRC Press, Taylor and Francis Group, LLC. 2016
5. Prigogine and S.A. Rice, New Methods in Computational Quantum Mechanics, Wiley.

M.Sc.					21MSP610T- 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 enable students to understand the importance of different characterization techniques.
- To introduce some state of the art characterization techniques.
- To provide fundamental concepts of experimental methods.

UNIT 1 Introduction to characterization techniques	10 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 Optical microscopy and diffraction methods	**12 Hrs.**
Optical microscope - Basic principles and components; Different examination modes (Bright field illumination, Oblique illumination, Dark field illumination, Phase contrast); Stereomicroscopy; Photo-microscopy; Applications. Fundamental crystallography; Generation and detection of X-rays; X-ray diffraction (XRD) techniques; XRD basics, geometry, instrumentation; Electron diffraction: Phase identification and cross sectional analysis	
UNIT 3 Electron microscopy and surface analysis	**10 Hrs.**
Interaction of electrons with solids; Scanning electron microscopy (SEM); Transmission electron microscopy (TEM): dark field, bright field imaging, high resolution mode; Specimen preparation techniques; Scanning transmission electron microscopy (STEM); Energy dispersive spectroscopy (EDS).	
UNIT 4 Advanced spectroscopic and some other techniques	**12 Hrs.**
Advanced Spectroscopic Techniques: UV-Visible Spectroscopy; Photo-luminescence spectroscopy; Infra-red spectroscopy; Raman spectroscopy; X-ray photoelectron spectroscopy (XPS). Scanning probe techniques: Principles of Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM); Laser Confocal Microscopy; Vibration sample and Superconducting quantum interference device (SQUID) magnetometry; Thermal studies: TGA.	
	Max. <44> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to
CO1 - Acquire basic knowledge about the fundamental processes associated with various characterization techniques
CO2 - Comprehend the significance of characterization in various fields of research
CO3 - Analyze the material properties using optical microscopy and diffraction techniques
CO4 - Analyze the material properties using electron microscopy and surface analysis
CO5 - Analyze the material properties using spectroscopic and other techniques

CO6 - Apply the knowledge gained in the different areas of research

TEXT/REFERENCE BOOKS

1. Fundamentals of Nanoscale Film Analysis, Alford, Feldmen and Mayer, Springer, 2007.
2. Experimental Techniques, Sam Zhang, CRC Press, 2009.
3. Elements of X-Ray Diffraction, Cullity, and Stock, Prentice-Hall, 2001.
4. Material characterization techniques, Kumar, Li, Zhang, CRC Press, 2008.

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

M.Sc. Course					21MSP621P- Advanced Condensed Matter Physics Laboratory					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**Viva**	
0	**0**	**6**	**3**	**6**	**0**	**0**	**0**	**50**	**50**	**100**

COURSE OBJECTIVES

- To understand and verify various underlying concepts of condensed matter physics.
- To gain practical knowledge and hands on various experimental set up in condensed matter physics.
- To acquire the skills for characterization of various samples for various properties.

List of experiments

1. Set the c-axis if the given crystal perpendicular to the incident x-ray beam.
2. Obtain the Laue photograph of the given single crystal draw gnomonic projections and index the reflections.
3. Obtain an oscillation photograph of the given single crystal about c-axis, calculate the c-dimension of the unit cell and index the reflections.
4. Determine the cell dimensions and establish the face centring of the copper and b Debye-Sherrer method.
5. Determine the value of the Hall coefficient of the given sample and determine the carrie concentration and carrier mobility.
6. Determine the relaxation time (EPR) of the given sample and the find value of g.
7. Determine the wavelength of a microwave output of a given reflex klystron oscillator and also to determine its repeller mode pattern.
8. Determine the specific heat of the given sample at room temperature and liquid nitrogen temperature.
9. Determine the Curie temperature of the given ferroelectric material.
10. Measurement of the critical temperature of the given HTc sample.
11. Study the thermo luminescence of a F centres in al alkali halide crystals.
12. Production and measurement of a low and high pressure.
13. Production and characterization of a plasma.
14. Study of Electron spins resonance.
15. Study of nuclear magnetic resonance.
16. Study of Mono and dia atomic lattice characterization.
17. Four probe measurement of magneto resistance and energy band gap of the semiconductor.
18. Verification of Wiedemann Franz law in metals,
19. Study of thermo-electric effect in various samples
20. Study of ferroelectric transition in ferroelectric materials
21. Study of Hysteresis loop in ferromagnets,
22. Determination of Susceptibility in paramagnetic fluids Quinkes method.

COURSE OUTCOMES

On completion of the course, the students will be able to

CO1 - Apply and analyse the concepts of condensed matter physics.

CO2 - Understand the practical knowhow of techniques for various structural determination.
CO3 - Demonstrate the dependence of electromagnetic properties of semiconductors on various factors.
CO4 - Investigate the effect of low and high pressure systems on various samples.

CO5 - Examine various thermoelectric effects in ferroelectric materials.
CO6 -Examine the phenomenon of superconductivity at room temperature and high critical temperature.

TEXT/REFERENCE BOOKS

1. N. W. Aschcroft and N. D. Mermin, Solid State Physics,CBS Publishing Asia Ltd., 1976
2. H. Ibach and H. Lueth, SOlid State Physics, An introduction to theory and experiment, Narosa Publishing House, 1992.
3. S. Blundell, Magnetism in Condensed Matter, 1st edition, Oxford University Press, 200.1
4. J. Singleton, Band Theory and electronic properties of solids, 1st edition Oxford University Press, 2001.

Evaluation

Max. Marks: 100

Continuous evaluation	50 marks
End semester examination, Viva-voce& project presentation	50 marks