TECHNO INDIA UNIVERSITY
WESTBENGAL

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2-Year Master of Science (M.Sc.) Curriculum and Syllabus for Physics

Third Semester

Course Code	Course Title	Credit
TIU-PPH-S201	Career Advancement Skill Development-III	3
TIU-PPH-T201	Material Physics I (Special Paper – I*)	3
TIU-PPH-T203	Nuclear Physics I (Special Paper – I*)	3
TIU-PPH-T205	Atomic and Molecular Physics	3
TIU-PPH-T207	Nuclear and Particle Physics	3
TIU-PPH-T213	Statistical Mechanics	3
TIU-PPH-T211	Introduction to Cryogenics	3
TIU-PPH-L201	General Physics Lab-II	3
TIU-PPH-P297	Project I	2
TIU-PES-S289	Entrepreneurship Skill Development	2
	Total	**25**

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SEMESTER III

TIU-PPH-T201: MATERIAL PHYSICS-I (SPECIAL PAPER – I) [L-T-P-C: 3-1-0-3]

Material Preparation and Characterisation: Preparation of materials by different techniques: Bulk crystal growth, Epitaxial growth, Thermal and electron evaporation technique, Sputtering, CVD, Melt and quenching, Gel desiccation. Characterization of material by XRD, thermal methods (DSC, DTA), Optical method (IR, FTIR, Raman), Microscopic (SEM, TEM, STEM, AFM etc.). Mechanical and electrical methods. Non destructive testing.

Phase Transformations in Materials: Diffusion and Thermodynamics of surfaces and interfaces, irreversible thermodynamics, kinetics of phase transformations, Salient features of solid-solid, solid-liquid phase transformations, Defects during solidification.

Physics of Semiconductors: Semiconductor materials - elemental & compound semiconductors & their properties Intrinsic & extrinsic semiconductors. Degenerate & compound semiconductors. Direct & indirect band gap semiconductors. Variation of energy bands for gr III– V ternary, quaternary alloys with alloy composition Concepts of Fermi level, Drift & Diffusion of carriers conductivity & mobility. Effect of Temperature and Doping. Hall Effect in semiconductors.
Excess carriers in semiconductors - low & high level injection, Generation & recombination process, Direct & indirect recombination, Concept of 'quasi' Fermi level. Basic equation for semiconductor device operations. Continuity equation, Current flow equation, Carrier transport equation, etc. Excess Carrier distribution in steady state, Minority Carrier life time & Diffusion length. Energy band diagram for homo & hetero junctions, p–n junctions, Effect of bias, calculation of built in potential, calculation of depletion width (W) & depletion layer capacitance, Current flow mechanism, Breakdown mechanisms.

Texts:
1. J. D. Plummer, Silicon VLSI Technology: Fundamentals, Practice and Modelling, Pearson Education .
2. S. M. Sze, Semiconductor Devices: Physics and Technology, Wiley.

Reference:
1. R. A. Swalin, Thermodynamics of Solids, John. Wiley and Sons, Inc.
2. D. A. Porter and K.E. Easterling, Phase Transformations in metals and alloys, CRC Press.

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TIU-PPH-T20 3: NUCLEAR PHYSICS I (SPECIAL PAPER – I) [L-T-P-C: 3-1-0-3]

Introduction: Survey of reactions of nuclei: Strong, electromagnetic and weak processes, Types of reactions and Q-values, Reaction mechanisms: Energy and time scales for direct and compound reactions, Experimental observables: Cross sections - definitions and units; Angular distributions, Excitation functions,

Models for nuclear reactions: Direct reactions: Optical Model: From Hamiltonian to cross sections for elastic scattering; Partial waves, Phase shifts, Scattering amplitudes, S-matrix and its symmetry and reciprocity; Angular distributions, Optical potential.

Transfer reactions, Spectroscopic factors, Asymptotic normalization constant (ANC).

Compound nuclear reactions : Statistical model.

R-matrix methods: Dispersion theory, One level formula.

Nuclear Astrophysics: Thermonuclear reactions: Reaction rates. Low energy behaviour and astrophysical S-factors, Forward and reverse reactions, Nonresonant and resonant reactions, Maxwell-Boltzmann distribution of velocities, Gamow peak.

Big Bang nucleosynthesis: He production, Be bottleneck, Abundance of light elements.

Stellar structure: Classical stars, Degenerate stars.

Nuclear burning in stars: H burning, He burning, Advanced nuclear burning, Core collapse.

Stellar nucleosynthesis: Abundance of elements, Production of nuclei, r-, s- and p-processes.

Texts:

1. K. S. Krane, Introductory Nuclear Physics, John Wiley (1988).
2. Claus E. Rolfs, William S. Rodney, Cauldrons in the Cosmos, University of Chicago Press
3. Ian J. Thompson, Filomena M. Nunes, Nuclear Reactions for Astrophysics: Principles, Calculation and Applications of Low-Energy Reactions, Cambridge University Publication (2009)

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TIU-PPH-T205: ATOMIC & MOLECULAR PHYSICS [L-T-P-C: 3-1-0-3]

Review of one-electron and two-electron atoms: spectrum of hydrogen, helium and alkali atoms;

Many electron atoms: central field approximation, Thomas-Fermi model, Slater determinant, Hartee-Fock and self-consistent field methods, Hund's rule, L-S and j-j coupling, Equivalent and nonequivalent electrons, Spectroscopic terms, Lande interval rule;

Interaction with Electromagnetic fields: Zeeman, Paschen Back and Stark effects; Hyperfine structure and isotope shift, selection rules; Lamb shift; Molecular spectra: rotational, vibrational, electronic, Raman and Infra-red spectra of diatomic molecules; electronic and nuclear spin, Hund's rule, Frank–Condon principle and selection rules;

Molecular structure: molecular potential; Born-Oppenheimer approximation, diatomic molecules, electronic angular momenta; Approximation methods; linear combination of atomic orbitals (LCAO) approach; states for hydrogen molecular ion; shapes and term symbols for simple molecules;

Spectroscopic techniques: basic principles of microwave, infrared, Raman, NMR, ESR and Mossbauer spectroscopies;

Modern developments: optical cooling and trapping of atoms, Bose-Einstein condensation, molecular spectroscopy in a magneto-optical trap, time resolved spectroscopy in the femto second regime.

LASER Spectroscopy: Spontaneous and Stimulated emission, Einstein's A, B coefficients, Optical Pumping, Population Inversion, Rate equation, modes of resonator and coherence length.

Texts:

1. B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules,2nd Ed. Pearson (2008).
2. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Ed.,Tata McGraw (2004).

References:

1. G. K. Woodgate, Elementary Atomic Structure, Clarendon Press (1989).
2. I. N. Levine, Quantum Chemistry, PHI (2009).
3. F. L. Pilar, Elementary Quantum Chemistry, McGraw Hill (1990).
4. H. E. White, Introduction to Atomic Spectra, Tata McGraw Hill (1934).
5. W. Demtroder, Atoms, Molecules and Photons, 2nd Ed., Springer (2010).
6. C. J. Foot, Atomic Physics, Oxford (2005).

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TIU-PPH-T207: NUCLEAR AND PARTICLE PHYSICS [L-T-P-C: 3-1-0-3]

Nuclear properties: radius, size, mass, spin, moments, abundance of nuclei, binding energy, semi-empirical mass formula, excited states; Nuclear forces: deuteron, n-n and p-p interaction, nature of nuclear force

Nuclear Models: liquid drop, shell and collective models; Nuclear decay and radioactivity: radioactive decay, detection of nuclear radiation, alpha, beta and gamma decays

Nuclear reactions: Different types of reactions, Quantum mechanical theory, Resonance scattering and reactions - Breit-Wigner dispersion relation, optical model, compound nucleus, direct reactions, resonance reactions, fission and fusion

Elementary particles: Fundamental forces, properties mesons and baryons, symmetries and conservation laws, quark model, concept of colour charge, discrete symmetries, properties, of quarks and leptons, gauge symmetry in electrodynamics, particle interactions and Feynman diagrams.

Texts:

1. K. S. Krane, Introductory Nuclear Physics, John Wiley (1988).
S. N. Ghoshal, Nuclear Physics, S. Chand & Company Ltd.

Reference:

1. R. R. Roy and B. P. Nigam, Nuclear Physics: Theory and Experiment, New Age (1967).
2. A. Das and T. Ferbel, Introduction to nuclear and particle physics, John Wiley (1994).
3. M. A. Preston and R. K. Bhaduri, Structure of the nucleus, Addison-Wesley (1975).
4. I. S. Hughes, Elementary Particles, Cambridge (1991).
5. F. Halzen and A. D. Martin, Quarks and Leptons, John Wiley (1984).
6. D. Perkins, Introduction to High Energy Pysics, Cambridge University Press; 4th edition (2000).

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TIU-PPH-T213: STATISTICAL MECHANICS [L-T-P-C: 3-1-0-3]

Statistical description: macroscopic and microscopic states for classical and quantum systems, connection between statistics and thermodynamics, entropy, classical ideal gas, entropy of mixing and Gibb's paradox;

Microcanonical Ensemble: Phase space, Liouville's theorem, applications of ensemble theory to classical and quantum systems;

Canonical Ensemble: partition function, thermodynamics in canonical ensemble, classical systems, ideal gas, energy fluctuation, equipartition and Virial theorem, system of harmonic oscillators, statistics of paramagnetism, negative temperature;

Grand Canonical Ensemble: equilibrium between a system and a particle-energy reservoir, partition function, density and energy fluctuation.

Formulation of Quantum Statistics: Quantum mechanical ensemble theory, density matrix, statistics of various ensembles, examples;

Theory of quantum ideal gases: Ideal gas in different quantum mechanical ensembles, identical particles, many particle wave function, occupation numbers, classical limit of quantum statistics, molecules with internal motion;

Ideal Bose Gas: Bose-Einstein condensation, blackbody radiation, phonons, Helium II;

Interacting Systems: Models of interacting systems, Ising, Heisenberg and XY models, Solution of Ising model in one dimension by transfer matrix method.

Texts:

1. R. K. Pathria and P. D. Beale, Statistical Mechanics, 3rd ed. Butterworth-Heinemann (2011).
2. S. R. A. Salinas, Introduction to Statistical Physics, Springer (2004).

References:

1. W. Greiner, L Neise, and H. Stocker, Thermodynamics and Statistical Mechanics, Springer (1994).
2. K. Huang, Statistical Mechanics, John Wiley Asia (2000).
3. L. D. Landau and E. M. Lifshitz, Statistical Physics, Pergamon (1980).

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TIU-PPH-T211: INTRODUCTION TO CRYOGENICS [L-T-P-C: 3-1-0-3]

What is cryogenics, its importance and applications. Production of low temperatures: Basics of Nitrogen & Helium liquefiers, Cryo refrigerators. Production of temperatures in mK range (Adiabatic demagnetization and Dilution refrigeration); Electrical, Thermal and Mechanical Properties of solids at cryogenic Temperatures; Cryogenic Temperature sensors and calibration; Temperature controls at cryogenic temperatures; Cryogenic level sensing & controls. Cryogenic safety practices.

Basic terminologies in vacuum physics, Flow regimes and applications; Conductance calculations; Production of vacuum from rough to ultra high vacuum ($\sim 10^{-12}$ torr): Rotary pumps, Oil diffusion pumps, Turbo-molecular pumps and Cryo pumps; Measurement of vacuum: Pirani and thermocouple gauges, Ionization gauges; Leak detection in vacuum systems; Basics of designing high and ultrahigh vacuum systems; Applications of vacuum technology.

Books Recommended:

1. Matter and Methods at Low Temperatures (Springer)…. Frank Pobell
2. Experimental Techniques in Low Temperature Physics (Clarendon Press) .G. K. White
3. Low Temperature Solid State Physics (Clarendon Press)… H. M. Rossenberg
4. Cryogenic Systems (Oxford Univ Press) … R. F. Barron
5. Cryogenic Engineering (CRC Press) … T M Flynn
6. Vacuum Technology (Third Edition) … *A. Roth*
7. Fundamentals of Vacuum Technology.. Revised & compiled by Dr. Walter Umrath (Leybold Vacuum)

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TIU-PPH-L201: GENERAL PHYSICS LABORATORY II [L-T-P-C: 0-0-6-3]

List of experiments:

Experiment 1: GM Counter

Experiment 2: Study of Plank's Constant,

Experiment 3: Study of Dielectric Constants

Experiment 4: Study of Hall effect in semiconductors,

Experiment 5: Study of Electron spin resonance (ESR) spectroscopy

Experiment 6: Study of wavelength of He – Ne Laser using ruler.

Experiment 7: Study of Fourier transform.

Experiment 8: Variation of efficiency of solar cell with frequency and angle of inclination and area

References:

1. R. A. Dunlop, Experimental Physics, Oxford University Press (1988).
2. A. C. Melissinos, Experiments in Modern Physics, Academic Press (1996).
3. E. Hecht, Optics, Addison-Wesley; 4 edition (2001).
4. J. Varma, Nuclear Physics Experiments, New Age Publishers (2001).
5. Laboratory Manual with details about the experiments.

*Special Paper – I (Any One) –

[A] Material Physics I
[B] Nuclear Physics I