

## Semester VII

### **Curriculum and Credit Framework for Undergraduate Programme of Physics Hons. (single Major) w.e.f. 2024 (NEP 2020)**

Course	Course Code	Name of the Paper	Course Type/ Nature	Teaching Scheme in hour per week			Credit	Marks
				Th	Pr	T		
CC- 16	PHSUMC C716	Statistical Mechanics	Theory	4	0	0	4	50 (ESE-40, IA-7, CA-3)
CC- 17	PHSUMC C717	Material Preparation and Semiconductor Physics	Theory	4	0	0	4	50
CC-18	PHSUMC C718	Statistical Mechanics (Python Programming) and Semiconductor Physics Practical	Practical	0	8	0	4	50 CIA=30 (Gr.A-15, Gr.B-15) ESE=20 (Expt=15, Viva=5)
DSE3	PHSUDSE 703	Analog and Digital Electronics Practical	Practical	0	8	0	4	50 CIA=30 (Gr.A-15, Gr.B-15) ESE=20 (Expt=15, Viva=5)
DSE4	PHSUDSE 704	Molecular Spectroscopy with applied Optics and Laser <b>(Only Hons. Student)</b>	Theory	4	0	0	4	50
RCW		Research Methodology & Ethics <b>Only Hons. With Research Students)</b>	Theory	4	0	0	4	50
GE1D (MIC)	PHSUMIC 704	Electricity and Magnetism	Practical	0	8	0	4	50 CIA=30 ESE=20 (Expt=15, Viva=5)

**Th**= Lecture, **T**= Tutorial, **Pr** = Practical, **CC** - Core Course, **DSE**=Discipline Specific Elective, **IA**= Internal Assessment, **CA**= Class attendance. **RCW**-Research Course Work,  
**CIA**=Continuous Internal assessment, **ESE**=End semester examination, **Expt.**=Experiment

## CC 16: STATISTICAL MECHANICS

(Credits: 04, Lectures 60)

*Students will learn about the behavior of macroscopic system by studying the statistical and probabilistic theory of large microscopic entities. Students will solve high level scientific problems using Python.*

**Classical Statistics:** Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations, Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature. Grand canonical ensemble and chemical potential. **(15 Lectures)**

**Classical theory of Radiation:** Properties of thermal radiation. Blackbody radiation. Pure temperature dependence. Kirchoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation pressure. Wien's displacement law. Wien's distribution law. Saha's ionization formula. Rayleigh-Jean's law. Ultraviolet catastrophe. **(10 Lectures)**

**Quantum Theory of Radiation:** Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.

**(8 Lectures)**

**Bose-Einstein Statistics:** B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Specific heat, Einstein's law and Debye's law. Bose derivation of Planck's law. **(15 Lectures)**

**Fermi-Dirac Statistics:** Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit. **(12 Lectures)**

### Reference Books:

- Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2<sup>nd</sup> Ed., 1996, Oxford University Press.
- Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
- Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall
- Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
- An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press.

## **CC17: Materials Preparation, Characterization and Semiconductor Physics** **(Credits: 04, Lectures 60)**

*The techniques involving the preparations of various forms of solid materials and the measurements to characterize the samples are essential parts of experimental Condensed matter physics. This course deals with the ideas behind all those aspects.*

Materials Preparation Techniques: Various methods of crystal growth, Preparation of Amorphous Materials, Thin films preparation (Poly-Crystalline & Amorphous), Glass and Glass Transition. Synthesis of low dimensional materials. Lithography, Arc Discharge, Thermal Evaporation, Sputtering, Chemical Vapour Deposition, Pulsed Laser Deposition, Molecular Beam Epitaxy, Electrodeposition and Sol-Gel Technique; **(10 Lectures)**

Material Characterization : X-ray Diffraction (XRD), XPS, Introduction to Microscopy: Advantages and disadvantages of optical microscopy over electron microscopy, Scanning electron Microscopy, Transmission Electron Microscopy, Scanning Tunneling Microscopy, Atomic Force Microscopy, Electron Spectroscopy for Chemical Analysis (ESCA), Optical Absorption & Transmission study by UV-VIS Spectro-Photometer, Photo Luminescence (PL), Introduction to thermal analysis: Phase changes, crystalline and amorphous fractions – DSC Thermo-gravimetric methods – TGA, DTA Energy Dispersive Analysis by X-ray (EDX). Neutron scattering and neutron diffraction, NMR **(15 Lectures)**

Different optical measurements: UV-VIS, PL, FTIR, Raman. Electrical measurements; Studies on various Conduction Mechanisms in 2D (thin films) and Low-dimensional Systems: Arrhenius type Thermally Activated Conduction, Variable Range Hopping Conduction and Polaron Conduction. **(8 Lectures)**

Concept of Vacuum techniques, production and measurement of low pressure, Pirani and Penning gauges, rotary and oil diffusion, Turbo, Ion, cryo-pumps; Elements of instruments, sensor materials. **(7 Lectures)**

**Semiconductor Physics:** Electron & Hole statistics in a semiconductor: Non degenerate & degenerate semiconductor, Intrinsic semiconductor, Ionization energy calculation, Distribution function over an impurity state, N type & P type semiconductor, **(8 Lectures)**

PN junction in equilibrium, Einstein Relation, Diffusion length, Derivation of diode equation, Junction capacitance, Metal Semiconductor junction. **(7 Lectures)**

Equilibrium & Non-equilibrium carriers, Photoconductivity & related device, Recombination via trap, Solar cell, Semiconductor laser, Hetero junction. **(5 Lectures)**

### **Books recommended:**

1. James F Shackelford, "Introduction to Materials Science for Engineers", 7<sup>th</sup> Edition, Pearson Prentice Hall, 2009
2. Callister W D, "Materials Science and Engineering: An Introduction", 7<sup>th</sup> Edition, John Wiley & Sons, Inc., 2007
3. Kenji Uchino, "Ferroelectric Devices", Marcel Dekker, INC, 2000.
4. Rao V V, Ghosh T B and Chopra K L, "Vacuum Science and Technology", Allied publishers Ltd.,

1998.

5. Leon I Maissel and Reinard Glang, "Hand Book of Thin Film Technology", McGraw Hill, 1970.
6. Kelsall Robert W, Ian Hamley and Mark Geoghegan, "Nanoscale Science and Technology", Wiley Eastern, 2004.
7. Bharat Bhushan, "Springer Handbook of Nanotechnology", 2004.
8. Michael Kohler, Wolfgang and Fritzsche, "Nanotechnology: Introduction to Nano structuring Techniques", Wiley –VcH, 2004.
9. Charles P Poole, Frank J Owens, "Introduction to Nanotechnology", John Wiley and Sons, 2003.
10. Gregory Timp, "Nanotechnology", Springer-Verlag, 1999.
11. Kireev: Semiconductor Physics
12. Streatman & Banerjee: Introduction to Solid State Electronics
13. Smith: Semiconductor
14. Dekker: Solid State Physics

## **CC18: Statistical Mechanics (Python Programming) and Semiconductor Physics Practical (Credits-4)**

### **Group-A**

#### **(Statistical Mechanics (Python Programming))**

#### **List of Computer Practicals using PYTHON and Scientific packages**

1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the *Lennard-Jones* potential, varying the total number of particles  $N$  and the initial conditions:
  - a) Study of local number density in the equilibrium state (i) average; (ii) fluctuations
  - b) Study of transient behavior of the system (approach to equilibrium)
  - c) Relationship of large  $N$  and the arrow of time
  - d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution
  - e) Computation and study of mean molecular speed and its dependence on particle mass
  - f) Computation of fraction of molecules in an ideal gas having speed near the most probable speed
2. Computation of the partition function  $Z(\beta)$  for examples of systems with a finite number of single particle levels (e.g., 2 level, 3 level, etc.) and a finite number of non-interacting particles  $N$  under Maxwell-Boltzmann, Fermi-Dirac and Bose- Einstein statistics:
  - a) Study of how  $Z(\beta)$ , average energy  $\langle E \rangle$ , energy fluctuation  $\Delta E$ , specific heat at constant volume  $C_v$ , depend upon the temperature, total number of particles  $N$  and the spectrum of single particle states.
  - b) Ratios of occupation numbers of various states for the systems considered above
  - c) Computation of physical quantities at large and small temperature  $T$

- and comparison of various statistics at large and small temperature T.
3. Plot Planck's law for Black Body radiation and compare it with Raleigh-Jeans Law at high temperature and low temperature.
  4. Plot Specific Heat of Solids (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debye distribution function for high temperature and low temperature and compare them for these two cases.
  5. Plot the following functions with energy at different temperatures
    - a) Maxwell-Boltzmann distribution
    - b) Fermi-Dirac distribution
    - c) Bose-Einstein distribution

**Reference Books:**

- Elementary Numerical Analysis, K.E. Atkinson, 3<sup>rd</sup> Edn . 2007 , Wiley India Edition
- Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2<sup>nd</sup> Ed., 1996, Oxford University Press.
- Introduction to Modern Statistical Mechanics, D. Chandler, Oxford University Press, 1987
- Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
- Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
- Statistical and Thermal Physics with computer applications, Harvey Gould and Jan Tobochnik, Princeton University Press, 2010.
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896
- Scilab by example: M. Affouf, 2012. ISBN: 978-1479203444
- Scilab Image Processing: L.M. Surhone. 2010, Betascript Pub., ISBN: 978- 6133459274

**Group-B**

**DSE3: Analog and Digital Electronics Practical  
(Credits:4)**

*These laboratory experiments are set up to supplement the fundamental knowledge behind the digital electronic circuits and principles.*

**Group-A  
(Analog Electronics )**

1. To develop a LC filter circuit having different cut-off frequencies and to find out frequency response characteristics.
2. To study the drain characteristics & transfer characteristics ( $I_D$  sat vs  $V_{gs}$  with  $V_{DS}$  as parameter) of a FET/MOSFET and to find out the drain resistance, mutual conductance and amplification factor.
3. To construct and design a regulated power supply using Op-Amp as comparator and power transistor as pass element and to find out its ripple factor and percentage of regulation.
4. To obtain the frequency response characteristic of an inverting operational amplifier and to find out its band width.
5. To obtain the frequency response characteristic of a non-inverting operational amplifier and to

- find out its band width.
6. Study of differential amplifier circuit using transistors and find out its differential mode gain.
  7. Determination of the slew rate of an Op-amp.
  8. To design and develop cascaded FET amplifier and to find out its linearity and frequency response characteristics.

Group-B  
(Digital Electronics)

1. To design a J-K master – slave flip-flop and to verify its truth table.
2. To design a 4 bit ripple counter and to develop different modulo counters from it
3. Design of a window comparator and study its characteristics
4. Monostable multivibrator and timer circuit with IC 555.
5. Simple microprocessor programming.

**DSE4: Molecular Spectroscopy with Applied optics and Laser**  
(Credit-4, Lectures-60)

*This course is intended to provide the fundamental ideas behind various spectroscopy. The origins and physical aspects of Microwave, Infra-red, Visible and Ultraviolet spectroscopy will be well explained. The last part deals with principles and techniques of Laser.*

**Microwave spectroscopy:** Classification of molecules, Diatomic molecular rotational spectroscopy of rigid and non-rigid diatomic molecules, triatomic molecules and polyatomic molecule, microwave spectroscopy of symmetric type of molecules, Stark effect. **(12 Lectures)**

**Infra-red spectroscopy:** Diatomic molecular vibrational spectroscopy with harmonic and anharmonic vibration, vibrational and rotational spectroscopy, anharmonic oscillation constant, rotational constant, Dissociation energy. **(10 Lectures)**

**Visible and ultraviolet spectroscopy:** Molecular electronic spectroscopy, Frank Condon principle, Molecular electronic vibrational-rotational spectroscopy, Born-Oppenheimer approximation, Fortrat diagram, Band head. **(12 Lectures)**

**Laser:** Laser resonator, population inversion, active and passive laser resonator, Threshold condition, saturation condition, Quality factor, classification of laser Three level laser and four level laser system, equation of population inversion and threshold power calculation for the laser systems, Ruby laser, He - Ne laser, CO<sub>2</sub> laser, Dye laser (tunable laser), Q swatching, mode locking, Application of laser. **(10 Lectures)**

**Fiber optics:** Different types (single and multi mode) of step index and graded index optical fiber, ray path in graded index optical fiber, Multipath broadening, Modal analysis of Electromagnetic waves in planer waveguide. Application of fiber in digital communication. **(10 Lectures)**

**Holography:** Coherent light and application of coherent light in holography. Recording and reconstruction of wave front. **(6 Lectures)**

### **Books Recommended:**

1. Fundamentals of Molecular Spectroscopy, by C. N. Banwell and E. M. McCah, Tata McGraw- Hill Publishing Company Limited, New Delhi.
2. Molecular Structure and Spectroscopy, by G. Aruldas, PHI Learning Private Limited, New Delhi.
3. Molecular Structure and Molecular Spectra: vol. 1, Spectra of Diatomic Molecules, 2<sup>nd</sup> ed., by G. Herzberg, Van Nostrand.
4. Molecular Structure and Molecular Spectra: vol. 2, Infrared and Raman Spectra of Polyatomic Molecules, by G. Herzberg, Van Nostrand.
5. Molecular Spectroscopy, by G. M. Barrow, Mc-Graw Hill.
6. Optical Electronics, by A. Ghatak and K. Thyagarajan, Cembridge University Press India Pvt. Ltd, New Delhi.
7. Fundamentals of Light Sources and Lasers, by Mark Csele, John Wiley & Sons, Inc.
8. Optical Electronics, by A. Ghatak and K. Thyagarajan, Cembridge University Press India Pvt. Ltd, New Delhi.
9. Semiconductor optoelectronic devices, by P. Bhattacharya, Prentice Hall publication
10. Optical Electronics, by A. Yariv, Holt McDougal

### **GE1D (MIC): Electricity and Magnetism Practical (Credit-4)**

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
2. To study the characteristics of a series RC Circuit.
3. To determine an unknown Low Resistance using Potentiometer.
4. To determine an unknown Low Resistance using Carey Foster's Bridge.
5. To compare capacitances using De'Sauty's bridge.
6. Measurement of field strength B and its variation in a solenoid (determine dB/dx)
7. To verify the Thevenin and Norton theorems.
8. To verify the Superposition, and Maximum power transfer theorems.
9. To determine self inductance of a coil by Anderson's bridge.
10. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
11. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
12. Measurement of charge and current sensitivity and CDR of Ballistic Galvanomete.
13. Determine a high resistance by leakage method using Ballistic Galvanometer.
14. To determine self-inductance of a coil by Rayleigh's method To determine the mutual inductance of two coils by Absolute method.

### **Reference Books**

- Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House

- A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11<sup>th</sup> Ed., 2011, Kitab Mahal
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4<sup>th</sup> Edition, reprinted 1985, Heinemann Educational Publishers
- Engineering Practical Physics, S.Panigrahi and B.Mallick, 2015, Cengage Learning.
- A Laboratory Manual of Physics for undergraduate classes, D.P. Khandelwal, 1985, Vani Pub.