Central University of Himachal Pradesh

Department of Physics and Astronomical Science

M. Sc. Physics

2nd Semester

Syllabus

2020

Statistical Mechanics

Course Code: PAS 406A **Course Type: Core Compulsory**
Course Credits: 4
Course Objectives:

Connection between Thermodynamics and Statistical Mechanics, Develop statistical mechanics techniques such as ensemble theory and their application to ideal and real systems.Theory of Phase transition.

Course Contents

Unit-1: Classical Statistical Mechanics (5 hours)

- Foundation of statistical mechanics.
- Specification of state of a system
- Contact between statistics and thermodynamic.
- Classical ideal gas, entropy of mixing
- Sackur-tetrode equation and Gibb's paradox.

Unit-2: Ensemble Theory: Microcanonical, Canonical Ensemble (6 hours)

- Phase space, phase-space trajectories and density of states
- Liouville theorem
- Microcanonical ensemble: Classical Ideal gas.
- Canonical ensemble: canonical partition function(CPF, average energy in canonical ensemble,)
- Relation between CPF and Helmholtz free energy
- Equivalence of canonical and microcanonical ensembles.

Unit-3: Ensemble Theory: Grand Canonical Ensemble (5 hours)

- Factorization of Canonical Partition function: Classical ideal gas
- Maxwell velocity distribution, Equipartition theorem
- Grand canonical ensemble: Partition function
- Calculation of statistical quantities, particle density and energy fluctuations.

Unit-4: Quantum Statistical Mechanics: Statistical Distributions (6 hours)

- Density matrix, statistics of ensembles.
- statistics of indistinguishable particle.
- Harmonic oscillator at temperature T, Maxwell-Boltzmann
- Fermi-Dirac and Bose-Einstein statistics: in microcanonical and grand canonical ensemble

Unit-5: Quantum Gases (7 hours)

- Ideal quantum gases: Bose gas, Fermi gas equation of state, energy density
- Standard functions, non-degenerate case
- Degenerate Fermi gas, Sommerfeld expansion: chemical potential and specific heat of degenerate Fermi gas
- Pauli paramagnetism: low and high temperatures
- Bose-Einstein condensation: Pressure and specific heat.

Unit-6: Approximate Methods and Ising Model **(7 hours)**

- Cluster expansion for a classical real gas
- Virial equation of state
- Ising model, mean field theories of the Ising model in three, two and one dimensions
- Exact solutions in one-dimension.

Unit-7: Theory of Phase transition **(4 hours)**

- Landau theory of phase transition
- Critical indices
- Scale transformation and dimensional analysis.

Prescribed Text Books:

1. Statistical Mechanics, Kerson Huang, Wiley
2. Statistical Mechanics, R. K. Pathria and Paul D. Beale, Elsevier.

Other Resources/Reference books:

1. Statistical and Thermal Physics, F. Reif.
2. Statistical Physics, Landau and Lifshitz.
3. Statistical Mechanics, R. Kubo.

Advanced Quantum Mechanics

Course Code:PAS 407A **Course Type: Core Compulsory**
Credits: 04
Course Objectives:

This course is the next step to learn quantum mechanics, which will cover addition of Angular Momentum, Symmetries in quantum mechanics, scattering Theory, Relativistic wave equations.

Course Contents

Unit 1: Time-dependent Perturbation Theory **(10 hours)**
Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations — Fermi's Golden rule; Sudden and adiabatic approximations.

Unit 2: Scattering Theory **(10 hours)**
Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts; Relation between sign of phase shift and attractive or repulsive nature of the potential; Scattering by a rigid sphere and square well; Coulomb scattering; Formal theory of scattering —Green's function in scattering theory; Lippman-Schwinger equation; Born approximation.

Unit 3: Symmetries in Quantum Mechanics **(8 hours)**
Conservation laws and degeneracy associated with symmetries; Continuous symmetries — space and time translations, rotations; Rotation group, homomorphism between SO(3) and SU(2); Explicit matrix representation of generators for j = 2 and j = 1; Rotation matrices; Irreducible spherical tensor operators, Wigner-Eckart theorem; Discrete symmetries — parity and time reversal; Identical particles.

Unit 4: Relativistic Quantum Mechanics **(12 hours)**
Klein-Gordon equation, interpretation of negative energy states and concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; Non-relativistic reduction; Helicity and chirality; Properties of gamma matrices; Charge conjugation; Normalisation and completeness of spinors.

Prescribed Text Books:

1. **J.J. Sakurai,** *Modern Quantum Mechanics*, **Addison-Wesley** (ISBN 0-201-06710-2).
2. **R. Shankar**, *Principles of quantum mechanics*, **Plenum Press**.
3. **D. J Griffiths,** *Introduction to Quantum Mechanics*, **Pearson PrenticeHall,** (2005).

Other Resources/ Reference Books:

1. **James D. Bjorken and Sidney D. Drell,** *Relativistic Quantum Mechanics,* McGraw-Hill Company, New York.
2. **G. Aruldhas,** *Quantum Mechanics*, PHI Learning, Eastern Economy Edition 2013.
3. **L. D. Landau and L. M. Lifshitz**, *Quantum Mechanics: Non-Relativistic Theory, Volume 3,* (Butterworth-Heinemann, 3rd edn, 1981)

Computer Simulations in Physics

Course Code: **PAS 414** **Course Type: Core Open**
Course Credit: 2

Course Contents:

Lab 1: Superposition of Waves

- Introduction to Scilab
- Fourier Series of square wave, triangle wave and other periodic waveforms

Lab 2: Construction of Wave packet

- using superposition of waves
- using Fourier transform

Lab 3: Solving the Time-Independent Schrodinger Equation using finite differences

- 1-D Finite Square Well potential using worksheet environment and using
- Comparision with analytically expected solutions

Lab 4: Propagator method

- Obtaining the energy eigen values using propagator method
- Finite square well
- Comparision with previous technique

Lab 5: Extension of Propagator method to

- Double Square well
- N-square wells

Lab 6: Matrix Methods

- Obtaining the energy eigen values and wavefunctions for
- Finite sqaure well potential
- Delta function potential

Lab 7: Extension of matrix method to

- Double well potential
- N-well potential

Lab 8: Matrix methods to solve

- Harmonic Oscillator using matrix methods
- Anharmonic Oscillator using matrix methods

Lab 9: Solving the Radial equation for Hydrogen atom using matrix methods

- Infinite Square well potential wavefunctions as basis functions
- Trying other basis functions

Reference: Department Lab Manual

Electronics Lab

Course Code: PAS- 415 **Course Type: Core Open**
Credits: 2

Experiments:

Lab 1: Negative Feedback Amplifiers and Instrumentation Amplifier

Lab 2: Regenerative Feedback System, Astable and Monostable Multivibrator

Lab 3: Integrators and Differentiators

Lab 4: Voltage Controlled Oscillator

Lab 5: Phase Locked Loop

Lab 6: DAC and ADC

Lab 7: Introduction to Arduino kit : Flashing of LED lights

Lab 8: Interactive Traffic Lights

Lab 9: Temperature Alarm

Lab 10: Any interesting project using Arduino kit

References:

1. Learning to Design Analog Systems using Analog System Lab Starter Kit, Dr. K.R.K. Rao and Dr. C.P. Ravikumar, Texas Instruments, India
2. Internet for Arduino

Accelerator and Reactor Physics

Course Code: PAS 528 **Course Type: Core Open Course**
Credit: 2

Course Objectives:

The course is designed to Review, Introduction: Historical view and main parts,,Types Design and Working of Accelerators and Reactors, Accelerators in CERN: LHC , Applications and Nuclear Safeguards

Course Contents

Unit 1: Accelerators **(3 hours)**

- Historical Developments, Layout and Components of Accelerators
- Electrostatic Accelerators, Linear Accelerators, SLAC
- Phase Stability, Low Energy Circular Accelerators

Unit 2: High Energy Accelerators **(4 hours)**

- Synchro-cyclotron, Proton Synchrotrons
- Colliding Beam Accelerators: Tevatron and Storage Rings
- Accelerators at CERN, Large Hadrons Collider (LHC)

Unit 3: Neutron Physics **(3 hours)**

- Neutron Sources, Absorption and Moderation of Neutrons
- Neutron Reaction and Cross-sections
- Neutron Capture

Unit 4: Nuclear Reactors **(7 hours)**

- Energy and Characteristics of Fission, Nuclear Chain Reaction
- Physics of the Nuclear Reactor and Critical Size of a Reactor
- Types, Design and Working of Fission Reactors
- Characteristics of Fusion, Thermonuclear Reactions, Fusion Reactors, Design of Fusion Power Plant

Unit 5: Applications& Nuclear Safeguards **(3 hours)**

- Indian Accelerators & Reactors, Nuclear Power, Reactor Safety, Domestic and International Nuclear Safeguards and Nuclear Waste Management.

Prescribed Textbooks:

1) D. C. Tayal: Nuclear Physics, Himalaya Publishing House Pvt. Ltd.
2) Kenneth S. Krane : Introductory Nuclear Physics, John Wiley & Sons, 1988.

Other Resources/Reference books:

1. S.Y. Lee: Accelerator Physics, World scientific, 2004.
2. W.M. Stacey: Nuclear Reactor Physics, Wiley-VCH Verlag GmbH & Co.
3. H. Staneley: Principles of Charged Particle Acceleration, John Wiley & Sons.

H. Wiedemann: Particle Accelerator Physics I, Springer, 1999

Electronic Circuits

Course Code: PAS 405 **Course Type: Core Open**
Credits: 2
Course Objectives:

The course is designed to under the detail of the basics of diode its types, characteristics and applications (diode circuits) like rectifiers, Clipper, Clamper, comparator, sampling gate etc. Integrated circuits as analog system building blocks: including linear and nonlinear analog systems. Integrated circuits: digital system building blocks including adders etc.

Course Contents

Unit 1:Transport Phenomena in Semiconductors **(4 hours)**

- Generation and recombination of charges
- Diffusion
- The continuity Equation
- Injected Minority charge carrier (low level injection)
- Potential variation with in a graded semiconductor

Unit 2:Junction Diode Characteristics **(5 hours)**

- Open circuit p-n junction diodes
- p-n junction as rectifier
- Current components in p-n junction diode
- Volt-ampere characteristics and its temperature dependence
- Diode resistance
- Space charge or transition capacitance, varactor diodes.
- Charge control description of diode
- Diffusion capacitance
- Junction diode switching times
- Breakdown diode
- Semiconductor photodiode
- Photovoltaic effect and light emitting diode

Unit 3:Diode Circuits **(4 hours)**

- Diode as circuit element
- The loade line concept
- piece wise linear diode model
- clipping circuit,
- clipping at two independent levels
- Clampers
- comparator, sampling gate
- rectifiers, and capacitor filter

Unit 4:Integrated Circuits as Analog System Building Blocks (3 hours)

- Basic Operational Amplifiers
- Differential amplifier and its transfer characteristics
- Frequency response of operational amplifiers

Unit 5:Analog Systems (4 hours)

- Linear Analog System: basic operational amplifier applications, differential dc amplifier, stable ac coupled amplifier, analog integration and differentiation, electronic analog computation, active filters.
- Non-Linear Analog System: comparators, logarithmic amplifiers, wave generators,

Prescribed Textbooks:

1. Integrated Electronics by Jacob Miliman and CristosHalkias, Tata McGraw-Hill Edition
2. Electronic device and circuit theory by Robert L. Boylestad and Louis Nashelsky, Pearson Education.

Other Resources/Reference books:

1. Operational Amplifiers Design and Applications by Jerald G. Graeme, Gene E. Tobey, Lawrence P. Huelsman, McGraw-Hill.
2. Digital Electronic Principles by A. P. Malvino, Tata McGraw Hill..
3. Electronic Devices and Amplifier Circuits by Steven T. Karris, Orchard Plications

History & Philosophy of Science

Course Code: PAS 417A **Course Type: Human Making**

Credits: 02

Course Objectives:

Given the nature of Foundational Course and learners from diverse background, the course is designed to provide an overview of the course to the students i.e. the introduction of eastern philosophical thoughts leading to the evolution of modern scientific paradigm. It will start with the Indian tradition of Science, philosophical thoughts and quest for understanding nature starting from Vedic era, through Greeks and Arabs to the European lead modern science. Finally, the connection between the Indian thought and modern science is also discussed. It is believed that after completion of this course the students will get a holistic insight into the understanding of nature.

Course Contents

Unit 1: Indian Tradition of Science (6 hours)

- Indian efforts for understanding nature and the ultimate reality since the ancient times- starting from the Vedic era to the modern times,
- Science in the ancient texts, Biology, Chemistry, Mathematics and Astronomy, nomenclatures, Scientific Literature,
- Life sketches of ancient Indian scholars,
- Indian schools of thoughts on understanding the origin and evolution of nature and force behind, Kal-Ganana,
- Historical damage to the science and scientific temper, Imprints of science in the Indian social setup i.e. Daily routine, Life style, Festivals and Rituals, Quotes by various researchers.

Unit 2: Nyaya and Vaisheshik Schools of Indian Thought (4 hours)

- Nine main Indian Schools of Thoughts,
- The Logics of Nyaya to Understand the Nature and its Dynamism;
- Atomic Theory- Concepts of Atom, Molecule and Mind in Pluralistic tradition of Vaisheshik,
- Basic elements, Motion and Action in Space and Time.

Unit 3: Western Ancient Schools of Thought (3 hours)

- Life sketches and contributions of Scientists and Philosophers,
- Before the Greeks (Pre-history-600 BCE),
- Ancient Greek Science (600 BCE – 300 BCE).

Unit 4: Evolution of Modern Science (5 hours)

- Period of Stagnancy,
- Scientific Revolution and enlightenment,
- Modern understanding of Life and Universe.

Unit 5: Parallel between Indian Thought and Modern Science (2 hours)

- The connection between the Indian thought and Modern Science,
- The Unity of all things,
- Beyond the world of opposites,
- Space-Time, The Dynamic Universe,
- Emptiness and Form,
- The Cosmic dance, Patterns of change and Interpenetration.

Prescribed Textbooks:

1. S.C. Chatterjee and D.M. Dutta, An Introduction to Indian Philosophy, Calcutta University Press (1948).
2. Thomas L. Isenhour, The Evolution of Modern Science, e-book at bookboon.com (2013).
3. Fritzoff Capra, Tao of Physics, Shambhala Pub. Inc.1975.

Other Recourses/Reference books:

1. Keshav Dev Verma, Vedic Physics, MotilalBanarsidass Publishers (2012).
2. P.T. Raju, The Philosophical Tradition in India MotilalBanarsidass Publishers (1992).
3. M. Curd, J.A. Cover and C. Pincock, Philosophy of Science, WW Norton & Co. London 2013.
4. Thomas S. Kuhn, The Structure of Scientific Revolution, the Univ. of Chicago Press, Chicago, 1970.

Elements of Scientific Programming

Course Code:PAS 428 B **Course: Skill Development**
Course Credit: 2

Motivation: Proficiency in computer programming/coding has arguably become one of the most important skills a researcher needs in science today. There are a number of reasons for this, prime among them is, as a consequence of advances in tools and technology, researchers are now collecting and working with larger datasets. These datasets require computing coding and machine learning steps for carrying out efficiently an unbiased and large scale analysis.

There are many ways to learn how to code and it is important to identify the method that works best for your science project. First you have to decide which computer language you are going to learn. A few of the bigger and recommended languages for science include Python, IDL, R, c++ etc.

Contents: This course will offer introductory coding classes that can be a great starting point to learn the basics of coding. Course will start by coding in IDL and Python, starting firstly for beginners and progressing to intermediate. As students might be from different disciplines, therefore the course will be general in nature. In second part of the course, the skill related to plotting and presentation of the scientific results based on the programing language such as IDL and Python as well as using the special plotting package such as GNU plot, Supermongo and PG-Plot will also be covered.

Finally, basic query for data mining from large science experiments and surveys, based on mysql and php programing, optimized by set of constraints by taking some example of research projects, will also be covered. For further advancement, few examples by using codes publically available in github repository which are also relevant for the area of research being pursued at the university, will be discussed by using them as subroutines in our planned main codes, so as to learn their use to carry out an unbiased and large scale analysis of large datasets existing in various public archives.