Central University of Himachal Pradesh

Department of Physics and Astronomical Science

Department Model Curriculum for M. Sc. Physics Programme

2019

M. SC. PHYSICS
2^{nd} Semester

Quantum Mechanics

Course Code:PAS 404 A **Course Type: Core Compulsory**
Credits: 4

Course Objectives:

The purpose of the course is to provide a comprehensive introduction and application of the quantum mechanics and develop pre-requisite for the next course 'Advanced Quantum Mechanics'. Starting from Fundamentals of Quantum Mechanics, Mathematical Formalism, Representation Theory, Eigenfunctions, Eigenvalues, Unitary Matrix, Schrodinger and Heisenberg representations; Energy Eigenvalue Problems; Matrix Representations, Angular Momentum Operators and Addition of Angular Momenta, Time Independent Perturbation Theory, Variational Principle and WKB Method.

Course Contents

Unit 1: Fundamentals of Quantum Physics (10 hours)

- Schrodinger's equation, Statistical interpretation of the wave function and normalisation
- Expectation values of operators, Ehrenfest's theorems
- Stationary solutions. Normalisable and non- normalizable states
- Eigenvalues and eigenfunctions, orthornormality and completeness of solutions
- Simple one- dimensional potentials: Square- well and delta function
- Free particle: Non-normalisable solutions, wave packets, box normalisation
- Momentum space representations, Perseval's theorem.

Unit 2: Mathematical Foundations (8 hours)

- Finite dimensional linear vector space and inner product spaces
- Dual spaces and the Dirac notation of bra and ket
- Linear transformations (operators) and their matrix representations
- Hermitian and unitary operators and their properties
- Generalisation to infinite dimensions
- Incompatible observables, Uncertainty relation for two arbitrary operators and it's proof.

Unit 3: Quantum dynamics (4 hours)

- Schroedinger picture: Unitary time evolution, Schrodinger equation
- Heisenberg picture: Heisenberg operators, Heisenberg's equation of motion
- Linear Harmonic Oscillator by operator method and it's time evolution.

Unit 4: Three dimensional problems (4 hours)

- Three dimensional problems in Cartesian and spherical coordinates
- Square wells and harmonic oscillator
- Hydrogen atom, Radial equation and it's solution.

Unit 5: Angular Momentum (4 hours)

- Angular Momentum Operators and their algebra
- Eigenvalues and Eigenfunctions
- Matrix representations for different j

- Spin Angular Momentum and Addition of Angular Momenta
- Clebsch-Gordan Coefficients.

Unit 6: Time Independent Perturbation Theory (6 hours)

- Basic Concepts, Non-degenerate Energy Levels
- First and Second Order Corrections to the Wave function and Energy
- Degenerate Perturbation Theory
- Relativistic correction and Spin-orbit Interactions
- Zeeman Effect and Stark Effect.

Unit 7: The Variation Method and WKB Approximation (4 hours)

- The Variation Principle, Rayleigh-Ritz Method
- Variation Method for Excited States
- Ground State of Helium
- WKB Method, Connection Formula
- Validity of WKB Method
- Tunnelling through a Barrier and alpha decay.

Prescribed Textbooks:

1. G. Aruldhas, Quantum Mechanics, PHI Learning, Eastern Economy Edition 2013.
2. W. Greiner, Quantum Mechanics-An Introduction, Springer-Verlag, Germany.
3. David J. Griffiths, Introduction to Quantum Mechanics, Pearson Prentice Hall, Inc.

Other Resources/Reference books:

1. Ashok Das, Quantum Mechanics, Tata McGraw Hill (2007).
2. Leonard. I. Schiff, Quantum Mechanics, 3rd edition, Tata McGraw-Hill 2010.
3. J.J. Sakurai, *Modern Quantum Mechanics*, Addison-Wesley ISBN 0-201-06710-2).
4. R. Shankar, Principles of Quantum Mechanics, Second edition, Plenum Press, New York.
5. E. Marzbacher, Quantum Mechanics, Wiley Student Edition, 2011.
6. Mathews and Venkateshan, Quantum Mechanics, Tata McGraw-Hill 2010.
7. P.A.M. Dirac, The Principles of Quantum Mechanics, Snowball Publishing.
8. A. Messiah, Quantum Mechanics, Dover Books on Physics.

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.

Electronic Circuits

Course Code: PAS 405 **Course Type: CoreOpen**
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 Phenomenain 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
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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 Cristos Halkias, 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

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

Computer Simulations in Physics

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

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 Equationusing 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

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, Motilal Banarsidass Publishers (2012).
2. P.T. Raju, The Philosophical Tradition in India Motilal Banarsidass 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.

Science of Yoga

Course Code:PAS 556 **Course: Skill Development Course**
Credits: 2

Techniques to be learnt:

- UpaYoga: Simple preparatory exercises for Suryanamaskar
- Suryanamaskar
- Yoga namaskar
- Few Asanas : Vajrasana, Bhujnagasana, Sarvangasana
- Pranayama : Bastrika, Anulom Vilom, Bramari, Udgita and Pranayam
- Mudras
- Five Tibeten Practices
- A Few Prayers: Gayatri Mantra, Gita Slokas and Shanti mantras

Prescribed Textbooks:

2. B.K.S. Iyengar, "Light on Yoga", Thorsons, 2006 edition
3. Thich Naht Hanh, "Silence", Rider, 2015
4. Sri Rangarajan Video on "Dinacharya"
5. Sadhguru, "Inner Engineering: A Yogi's Guide to Joy" Penguin Publisher, 2016
6. Sri Sri Ravishankar, "Patnajali Yoga Sutras", Sri Sri Publicaitons Trust, 2012
7. Baba Ramdev Video on "Pranyaama"
8. Dr. Renu Mahatani, "Power of Pranayama", Jaico, 2017
