Course Allocation for Semester starting August 2019:

B.Sc I Semester				
Course Title	**Course Code**	**Course Credit**	**Hours/ week**	**Teacher**
Mathematical Physics- I	PAS 101	4		**Dr. Ayan Chatterjee**
Mathematical Physics- I Lab	PAS 101L	2		**Dr. Ayan Chatterjee & Dr. Jagdish Kumar**
Mechanics	PAS 102	4		**Dr. Surender Verma**
Mechanics Lab	PAS 102L	2		**Dr. Surender Verma**
Chemistry-1	CCS 101	4		**Dr. Subhanker Chetterjee**
Chemistry-1 Lab	CCS 101L	2		**Dr. Subhanker Chetterjee**
Eng/MIL-1		2		**Prof. Roshan Lal Sharma**
HM-1		2		**Dr. Anurag Linda**
		22	**0**	

B.Sc III Semester				
Course Title	**Course Code**	**Course Credit**	**Hours/ week**	**Teacher**
Mathematical Physics- II	PAS 201	4		**Dr. Rajesh Kumar Singh**
Mathematical Physics- II Lab	PAS 201L	2		**Dr. Rajesh Kumar Singh**
Thermal Physics	PAS 202	4		**RP 1**
Thermal Physics Lab	PAS 202L	2		**RP 1**
Digital Systems and Applications	PAS 203/**NOC18_ee33**	4		**RP 2**
Digital Systems and Applications Lab	PAS 203L	2		**RP 2**
Mathematics-1	MTH 101	4		**RP 5**
Mathematics-1 Tutorial	MTH 101 T	2		**RP 5**
		24	0	

B.Sc V Semester				
Course Title	**Course Code**	**Course Credit**	**Hours/ week**	**Teacher**
Quantum Mechanics & Applications	PAS 355	4		**RP 3**
Quantum Mechanics & Applications Lab	PAS 355 L	2		**RP 3**
Solid State Physics	PAS 302	4		**Dr. Jagdish Kumar**
Solid State Physics Lab	PAS 302L	2		**Dr. Jagdish Kumar & Dr. Rajesh Kumar Singh**
Nuclear and Particle Physics	PAS 318	4		**Dr. Dalip Singh Verma**
Nuclear and Particle Physics Lab/Tutorial	PAS 318L	2		**Dr. Dalip Singh Verma**
Astronomy and Astrophysics	PAS 319	4		**RD 4**
Astronomy and Astrophysics Physics Lab	PAS 319 L	2		**RD 4**
		24	**0**	

M.Sc I Semester				
Course Title	**Course Code**	**Course Credit**	**Hours/ week**	**Teacher**
Classical Mechanics	PAS 401A	4		**Dr. Surender Verma**
Electro-dynamics	PAS 403A	4		**RP 6**
Quantum Mechanics	PAS 404A	4		**Dr. Ayan Chatterjee**
General Physics Laboratory	PAS 413	2		**Dr. Surender Verma & Dr. Ayan Chatterjee**
Mathematical Physics	PAS 402	2		**RP 6**
History & Philosophy of Science	PAS 417 A	2		**Prof. B.C. Chauhan**
Science of Yoga	PAS 556	2		**Prof. O.S.K.S. Sastri**
		20	**0**	

M.Sc III Semester				
Course Title	**Course Code**	**Course Credit**	**Hours/ week**	**Teacher**
Condensed Matter Physics	PAS 408A	4		**Dr. Jagdish Kumar**
Nuclear and Particle Physics	PAS 409A	4		**Dr. Dalip Singh Verma**
Atomic, Molecular and Laser Physics	PAS 411A	4		**RP 7**
Quantum Field Theory	PAS 426A	4		**Prof. B.C. Chauhan**
Modern Physics Laboratory	PAS 423	2		**Dr. Dalip Singh Verma**
Modeling and Simulation	CSI 411	2		**RP 7**
		20	**0**	

Course Allocation for Semester starting Jan 2020:

B.Sc II Semester					
Course Title	**Course Code**	**Course Credit**	**Hours/ week**	**Course Type**	**Teacher**
Electricity and Magnetism	PAS 103	4	4	**Core Course**	RP1
Electricity and Magnetism Lab	PAS 103 L	2	4	**Core Course Lab**	RP1+
Waves and Optics	PAS 104	4	4		JK+RP5
Waves and Optics Lab	PAS 104 L	2	4		JK
Chemistry-2	CCS 102	4	4	**General Elective**	CHEM
Chemistry-2 Lab	CCS 102 L	2	4	**General Elective Lab**	CHEM
Eng/MIL -(2)		2	2		ENG
ENV		2	2		ENV
		24	28		

B.Sc IV Semester					
Course Title	**Course Code**	**Course Credit**	**Hours/ week**	**Course Type**	**Teacher**
Mathematical Physics- III	PAS 212	4	4	Core Course	AC
Mathematical Physics- III Lab	PAS 212 L	2	4	Core Course Lab	AC
Elements of Modern Physics	PAS 205	4	4	Core Course	SV
Elements of Modern Physics Lab	PAS 205 L	2	4	Core Course Lab	SV+RP 5
Analog System and Applications	PAS 206	4	4	Core Course	RKS
Analog System and Applications Lab	PAS 206 L	2	4	Core Course Lab	RKS
Theory of Equations and Analytical Geo	MTH 103	4	4		Math RP 2
Theory of Equations and Analytical Geo Tutorial	MTH 103 T	2	2		Math RP 2
		24	30		

B.Sc VI Semester					
Course Title	**Course Code**	**Course Credit**	**Hours/ week**	Course Type	Teacher
Electro-magnetic Theory	PAS 303	4	4	Core Course	RP 3
Electro-magnetic Theory Lab	PAS 303 L	2	4	Core Course Lab/Tutorial	HC+RP 3
Statistical Physics	PAS 304	4	4	Core Course	JK
Statistical Physics Lab	PAS 304 L	2	4	Core Course Lab	RP 1+RP 4
Classical Dynamics	PAS 316	4	4	Elective Specialization	RP 4
Classical Dynamics Lab	PAS 316 L	2	4	Elective Specialization Lab/Tutorial	RP 4+RP 3
Nano Materials and Applications	PAS 356	4	4	Elective Specialization	RP 5
		22	**28**		

M.Sc. II Semester					
Course Title	**Course Code**	**Course Credit**	**Hours/week**	**Course Type**	**Teacher**
Statistical Mechanics	PAS 406 A	4	4	Core- Compulsory(CC)	SV
Advanced Quantum Mechanics	PAS 407 A	4	4	Core- Compulsory(CC)	AC
Computer Simulations in Physics	PAS 414	2	2	Core-Open(CO)	OSKSS
Electronics Lab	PAS 415	2	4	Core-Open(CO)	RKS+
Accelerator and Reactor Physics	PAS 528	2	2	Core-Open(CO)	DSV
Electronics Circuits	PAS 405	2	2	Core-Open(CO)	DSV
Elements of Scientific Programming	PAS 428 B	2	2	Foundation Skill(FS)	HC
HM(History and Philosophy of Science)	PAS 417A	2	2	Human Making(HM)	BCC
		20	22		

M.Sc. IV Semester					
Course Title	**Course Code**	**Course Credit**	**Hours/week**	**Course Type**	**Teacher**
Computational Physics	PAS 428 A	4	4	Core- Compulsory(CC)	OSKSS
Computational Physics Laboratory	PAS 427	2	4	Core-Open(CO)	OSKSS+
Theoretical Nuclear Physics	PAS 527	4	4	Elective Specialization(ES)	DSV
Elementary Particles and Interactions	PAS 549	4	4	Elective Specialization(ES)	BCC
Project /Seminar	PAS 548 / PAS 520	4	4	Elective+ Specialization	All Faculty
Cosmology	PAS 539A	2	2	Elective Open	HC
		20	22		

Electricity & Magnetism (PAS103)

(Credit: 4, Duration: 10-15 weeks, Instructor: Dr. Padmnabh Rai)

Objectives & Academic Requirements: The emphasis of course is to teach basics of electricity and magnetism and their applications in solving problems of interest to physicists. The students are to be examined entirely on the basis of problems (seen/unseen) and assignments.Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in the examination.

Course Contents:

1. Electric Field& Electric Potential: Electric field, Electric field lines, Electric flux, Gauss' Law with applications to charge distributions (spherical, cylindrical and planar symmetry),Conservative nature of Electrostatic Field, Electrostatic Potential, Laplace's and Poissonequations, The Uniqueness Theorem, Potential and Electric Field of a dipole, Force and Torque on a dipole, Electrostatic energy of system of charges, Electrostatic energy of a charged sphere, Conductors in an electrostatic Field, Surface charge and force on a conductor, Capacitance of a system of charged conductors, Parallel-plate capacitor, Capacitance ofan isolated conductor, Method of Images and its application to: (1) Plane Infinite Sheetand (2) Sphere. (10 Lectures)
2. Dielectric Properties of Matter: Electric Field in matter, Polarization, PolarizationCharges, Electrical Susceptibility and Dielectric Constant, Capacitor (parallel plate,spherical, cylindrical) filled with dielectric, Displacement vector (D), Relations between (E, P and D), Gauss' Law in dielectrics. (5 Lectures).
3. Magnetic Field: Magnetic force between current elements and definition of MagneticFieldB, Biot-Savart's Law and its simple applications (straight wire and circular loop), Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with ElectricDipole), Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid, Properties of B(curl and divergence), Vector Potential, Magnetic Force on (1) pointcharge (2) current carrying wire (3) between current elements, Torque on a current loopin a uniform Magnetic Field. (10 Lectures)
4. Magnetic Properties of Matter: Magnetization vector (M), Magnetic Intensity(H),Magnetic Susceptibility and permeability, Relation between B, H, M, Ferromagnetism, B-H curve and hysteresis. (5 Lectures)
5. Electromagnetic Induction: Faraday's Law, Lenz's Law, Self-inductance and MutualInductance,

Reciprocity Theorem, Energy stored in a Magnetic Field, Introduction toMaxwell's Equations, Charge Conservation and Displacement current. (5 Lectures)

6. Electrical Circuits: AC Circuits (Kirchhoff's laws for AC circuits), Complex Reactanceand Impedance, Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width, Parallel LCR Circuit. (5 Lectures)

References:

1. Introduction to Electrodynamics, D.J. Griffiths, Prentice Hall (1998).
2. Electricity and Magnetism, E. M. Purcell, McGraw-Hill Education (2015).
3. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M. Sands, Pearson Education (2008).
4. Elements of Electromagnetics, M.N.O. Sadiku, Oxford University Press (2010).
5. Electricity and Magnetism, J. H. Fewkes& J. Yarwood, Vol. I, Oxford Univ. Press (1991).

Evaluation Criteria:

1. Mid-Term Examination: The weightage of mid-term exam will be 25% (50 marks) and tentative schedule will be 5th week of the academic secession.
2. End-Term Examination: The weightage of end-term exam will be 50% (100 marks) and tentative schedule will be 10thweek of the academic secession.
3. Internal Assessment: The weightage of internal assessment will be 25% (50 marks). The evaluation will be based on assignments, problems solving and quizzes.

Electricity & Magnetism Lab (PAS 103 L)

Course Name: Electricity & Magnetism Lab

Course Code: PAS 103 L

Credits: 2

Duration: 10-15 weeks

Instructor:Dr. Padmnabh Rai

List of Experiment:

1. Use a Multi-meter to measure (a) Resistances, (b) Capacitances, and (c) AC and DC Voltages.
2. To measure the magnetic field along the axis of a circular coil and verify Biot-Savart law.
3. To verify the law of resistance in series and parallel combination by using Multi-meter and breadboard.
4. Find the voltage drop and current across lead resistance by using Thevenin and Norton theorem in network circuit.
5. To plot the AC phase shift in resistance-capacitor (RC) and resistance-inductor (RL) circuit by usingexpeyes instrument.
6. To plot the graph of transient response of RL, RC, LCR circuit by using expeyes instrument.
7. To get triangular wave by integrating squire wave and differentiated to get spikes at the transition in RC circuit by using expeyes instrument.
8. To study AC phase shift, transient response, and integration & differentiation of squire wave by using CRO and function generator.

References:

6. Introduction to Electrodynamics, D. J. Griffiths, Prentice Hall (1998).
7. Electricity and Magnetism, E. M. Purcell, McGraw-Hill Education (2015).
8. Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, Asia Publishing House (1971).
9. A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Ed, Kitab Mahal (2011).
10. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted, Heinemann Educational Publishers (1985).
11. Engineering Practical Physics, S. Panigrahi and B. Mallick, Cengage Learning (2015).

Course Contents

Course Code: PAS 104 (Theory) Course

Name: Waves and Oscillations Credits

Equivalent: 4 Credits

Course Objectives: The emphasis of course is to introduce students to concepts and phenomena related to waves and oscillations. The application of these concepts to real life examples will be discussed.

Attendance Requirements:

Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in the examination.

Attendance:

Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student will not be permitted to appear in examination.

Evaluation Criteria:

The overall evaluation of the students shall be for 200 marks distributed as per following scheme.

1. Mid Term Examination 25% (50 marks)
   At the end of 5th week the midterm examination shall be held for duration of *two hours* and shall consist of 50 marks question paper. The question paper shall consist of three sections. Section A (10 marks) shall contain 5 to10 very short answer type questions of 2/1 marks each, all being compulsory. Section B (20 marks) shall contain 6 short answer type questions of 5 marks each, out of which students have to attempt any 4. Section C (10 marks) shall consist of 2 compulsory long answer type questions of 10 marks each. The questions in section C shall have internal choice.
2. End Term Examination 50% (100 marks)
   At the end of 10th week the end term examination shall be held for duration of *three hours* and shall consist of 100 marks question paper. The question paper shall consist of three sections. Section A (20 marks) shall contain 10 to 20 very short answer type question of 2/1 marks each, all being compulsory. Section B (30 marks) shall contain 9 short answer type questions of 5 marks each, out of which students have to attempt any 6. Section C (50 marks) shall consist of 5 compulsory long answer type questions of 10 marks each. Every question in section C shall have internal choice.
3. Continuous Internal Assessment 25% (50 Marks):
   Consisting of assignments/quizzes/presentation/live projects, shall contribute 20% of the total 200 marks i.e. (40M) and 5% of the marks (i.e. 10M) towards internal assessment shall be on the basis of attendance.

UNIT-I Oscillations (31 Lectures)

Basic concepts of Simple Harmonic Oscillations (SHM): Equation of motion and its solution, Amplitude, frequency, time period, phase, velocity and acceleration. Kinetic and potential energy and their time averages. Reference circle and rotating vector representation of SHM. (4 Lectures)

Free Oscillations of Systems with One Degree of Freedom: mass-Spring system, Simple Pendulum, Torsional Pendulum, Oscillations in a U-Tube, Compound pendulum (Centres of Percussion and Oscillation) and Bar Pendulum. (5 Lectures)

Superposition of Two Collinear Harmonic oscillations: Linearity and Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats). (5 Lectures)

Superposition of Two Perpendicular Harmonic Oscillations: Frequency Ratios 1:1 and 1:2 using graphical and Analytical Methods. Lissajous Figures and their uses.

(5 Lectures)

System with Two Degrees of Freedom: Coupled Oscillators. Normal Coordinates and Normal Modes. Energy Relation and Energy Transfer. Normal Modes of N Coupled Oscillators. (6 Lectures)

Damped and Forced Oscillations: Damped Oscillations: Damping Coefficient, Log Decrement, Transient and Steady States, Amplitude, Phase, Resonance, Sharpness of Resonance, Power Dissipation and Quality Factor. Helmholtz Resonator.

(6 Lectures)

UNIT-II Waves (19 Lectures)

Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave.
Water Waves: Ripple and Gravity Waves. (5 Hours)

Velocity of Waves: Velocity of Transverse Vibrations of Stretched Strings. Velocity of Longitudinal Waves in a Fluid in a Pipe. Newton's Formula for Velocity of Sound. Laplace's Correction. (6 Hours)

Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String (Fixed and Free Ends) Analytical Treatment. Phase and Group Velocities, Changes with respect to Position and Time. Energy of Vibrating String, Transfer of Energy, Normal Modes of Stretched

Strings. Plucked and Struck Strings. Melde’s Experiment. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of *N* Harmonic Waves.

(8 Hours)

Key Texts:

1. Vibrations and Waves by A. P. French.(CBS Pub. & Dist., 1987)

2. The Physics of Waves and Oscillations by N.K. Bajaj (Tata McGraw-Hill, 1988)

Reference texts:

3. Vibrations and Waves, Banjamin Crowell, Light & Matter Series (www.lightandmatter.com)

4. Fundamentals of Waves & Oscillations By K. Uno Ingard (Cambridge University Press, 1988)

5. An Introduction to Mechanics by Daniel Kleppner, Robert J. Kolenkow (McGraw-Hill, 1973)

6. Waves: BERKELEY PHYSICS COURSE (SIE) by Franks Crawford (Tata McGrawHill, 2007).

Course Contents

Course Code: PAS 104L

Course Name: Waves and Oscillations (Lab)

Credits Equivalent: 2 Credits

Course Objectives: To demonstrate the ideas of waves and oscillations and their applications in day to day life.

List of Experiments

1. To find and compare force constant of different springs and obtain spring constant when connected in series and parallel.
2. To determine damping coefficient, logarithmic decrement of a damped harmonic oscillator.
3. To study resonance in forced harmonic oscillator
4. To study beats formation due to superposition of two harmonic oscillations
5. To find out angular frequency of individual normal modes (symmetric and asymmetric) of coupled harmonic oscillator.
6. To calculate acceleration due to gravity using Kater's pendulum.
7. To determine frequency of electrically maintained vibrator using transverse mode and then study effect of length and tension in string using Melde's experiment.
8. To study superposition of waves using computer programming.
9. Observation of Lissajous figures: using computer program and CRO.
10. To determine the frequency of symmetric and asymmetric oscillations of a double pendulum.

Reference Books:

7. D.P. Khandelwal, "A laboratory manual for undergraduate classes" (Vani Publishing House, New Delhi).
8. S.P. Singh, "Advanced Practical Physics" (Pragati Prakashan, Meerut).
9. Worsnop and Flint- Advanced Practical physics for students.
10. "Practical Physics" R.K Shukla, Anchal Srivastav

Course Code: PAS 202
Course Name: Thermal Physics
Course Instructor: Dr. Ayan Chatterjee
Course Duration: 10 weeks

Credits Equivalent: 4 Credits (One credit is equivalent to 10 hours of lectures/organised classroom activity/contact hours; 5 hours of laboratory work/practical/field work/Tutorial/teacher-led activity and 15 hours of other workload such as independent individual/group work; obligatory/optional work placement; Reading / listening to self-learning modules, literature survey / library work; data Collection /field work; writing of papers/projects/dissertation/thesis/seminars, etc.)

Course Objectives: The study of thermal physics and its applications pervades much of the modern undergraduate course in physics. Virtually all undergraduates are expected to become familiar with the principles of thermodynamics and Kinetic theory, and their applications to real life examples.. This following material is the subject of this course.

Attendance Requirements:

Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in the examination.

Evaluation Criteria:

The overall evaluation of the students shall be for 100 marks distributed as per following scheme.

1. Mid Term Examination 25% (50 marks)
2. End Term Examination 50% (100 marks)
3. Continuous Internal Assessment 25% (50Marks): Consisting of assignment/quizzes/presentation/ live projects, shall contribute 20% of the total 200 marks and 5% of the marks towards internal assessment shall be on the basis of attendance.

COURSE CONTENTS

1. Kinetic Theory of Gases: (20 Lectures)

Basic assumptions of kinetic theory, Ideal gas approximation, and deduction of perfect gas laws. Maxwell's distribution law (both in terms of velocity and energy), root mean square and most probable speeds. Experimental proof. (6)
Finite size of molecules: Collision probability, Distribution of free paths and mean free path from Maxwell's distribution. Clausius and Maxwell's derivation of mean free path. (4)
Degrees of freedom, equipartition of energy: application to specific heat, Dulong and Petit's law.(1)

Transport Phenomena: Viscosity, thermal conduction and diffusion in gases. Brownian Motion: Einstein's theory, Perrin's work, determination of Avogardo number.(4)

Real Gases: Nature of intermolecular interaction, deviations from ideal gas law, isotherms of real gases. van der-Waal's equation of state, Other equations of state, critical constants of a gas, law of corresponding states; Virial Coefficients, Boyle temperature; limitations of van der- Waal's equation of state.(5)

2. Thermodynamics: (20 Lectures)

Basic Concepts: Microscopic and macroscopic points of view : thermodynamic variables of a system, State function, exact and inexact differentials. Thermal equilibrium,. Zeroth Law and the concept of temperature. (2)

First Law of Thermodynamics: Thermodynamic equilibrium, internal energy, external work, quasistatic process, first law of thermodynamics and applications including magnetic systems, specific heats and their ratio, isothermal and adiabatic changes in perfect and real gases. (5)

Second Law of Thermodynamics: Reversible and irreversible processes, indicator diagram. Carnot cycles-efficiency, Carnot's theorem. Kelvin's scale of temperature, relation to perfectgas scale, second law of thermodynamics – different formulations and their equivalence, Clausius inequality, entropy, change of entropy in simple reversible and irreversible processes, entropy and disorder; equilibrium and entropy principle. (7)

Thermodynamic Functions: Enthalpy, Helmholtz and Gibbs' free energies; Legendre transformations, Maxwell's relations and simple deductions using these relations; thermodynamic equilibrium and free energies. Porous plug experiment and the Joule- Thomson effect. (6)

Text Books:

1. A treatise on heat: M.N. Saha and B. Srivastava, Indian Press,1958.
2. Heat and thermodynamics: M. Zemansky, McGraw Hill, 1981.
3. Kinetic theory of gases: J. Jeans, Cambridge University Press.

Reference Books:

1. Thermostatics: H. Callen, Wiley, 1960.
2. Kinetic theory of gases: Loeb, Chicago university press.
3. Thermal physics: Kittel, Wiley, 1950.
4. Thermodynamics, M. Planck, Dover.

There are large numbers of books on thermodynamics and many of them are classics. You are encouraged to read from them too.

Course Code: PAS 301

Course Name: Quantum Mechanics

Course Instructor: Dr. Surender Verma

Course Contents

UNIT-I

Inadequecies in classical physics, Black body radiation: quantum theory of light, photoelectric effect, Compton effect, Frank-Hertz, experiment, Wave nature of matter: De Broglie hypothesis, wave-particle duality, Davisson-Germer experiment, Wave packets, group and phase velocities and relation between them, two slit experiment with electrons, probability, wave amplitude and wave function, Heisenberg uncertainty principle involving canonical pair of variables.

UNIT-II

Basic postulates and formalism: Energy, momentum and Hamiltonian operators, time independent Schrodinger equation for stationary states, properties of wave function, probability density and probability, continuity equation, conditions for physical acceptibility of wave function, normalization, linearity and superposition principles, eigenvalues and eigen functions, expectation values, wave function for a free particle.

UNIT-III

Eigenfunction and eigenvalues of a particle in a one-dimensional box, Bound state problems: General features of a bound particle system: one dimensional harmonic oscillator: energy levels, energy eigen function and zero point energy.

UNIT-IV

Quantum theory of Hydrogen atom: particle in a spherical symmetrical potential, Schrodinger equation, separation of variables, radial solutions and principal quantum number, orbital and magnetic quantum numbers, Quantization of energy and angular momentum, space quantization.

UNIT-V

Scattering problems in one-dimension: Finite potential step: reflection and transmission, stationary solutions, Probability current, attractive and repulsive potential barriers. Quantum phenomenon of tunneling: tunnel effect. Finite potential well (square well).

Text Books:

1. Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed. 2005, Pearson Education.
2. Concepts of Modern Physics, Arthur Beiser, Tata-McGraw Hill.
3. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.

Additional Books for Reference:

1. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
2. Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
3. Quantum Mechanics, Walter Greiner, 4th Edn., 2001, Springer.

Course Name: Nuclear and Particle Physics Course code: PAS318

Credit: 4 Total Lecture (40)

Course Contents:

Unit: I General Properties of Nuclei (6 Lecture)

Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states.

Unit: II Nuclear Models (6 Lectures)

Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermigas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

Unit: III Radioactivity decay (6 Lectures)

(a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion.

Unit IV: Nuclear Reactions (5 Lectures)

Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

Unit V Interaction of Nuclear Radiation with matter (5 Lectures)

Energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation, Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.

Unit VI Detector for Nuclear Radiations (6 Lectures)

Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter, Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT), Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.

Unit VII Particle physics: (6 Lecture)

Particle interactions; basic features, types of particles and its families, Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark, model, color quantum number and gluons.

Electronic Circuits

Course Code: PAS405 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 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..
   1. Electronic Devices and Amplifier Circuits by Steven T. Karris, Orchard Plications

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 one dimension
- 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

Course Credit: 4

Credits Equivalent:

4 Credits (One credit is equivalent to 10 hours of lectures/organised classroom activity/contact hours; 5 hours of laboratory work/practical/field work/Tutorial/teacher-led activity and 15 hours of other workload such as independent individual/group work; obligatory/optional work placement; Reading/listening to self-learning modules, literature survey/library work; data collection/field work; writing of papers/projects/dissertation/thesis/seminars, etc.)

Course Objectives:

Quantum physics allows us to understand the nature of the physical phenomena which govern the behavior of solids, semiconductors, lasers, atoms, nuclei, sub nuclear particles, and light. In the present course, the basic formalism of the fundamentals of quantum physics will be discussed using an original approach which relies primarily on an algebraic treatment and on the systematic use of symmetry principles.

The study of quantum mechanics and its applications pervades much of the modern undergraduate course in physics. Virtually all physics students are expected to become familiar with the principles of non-relativistic quantum mechanics, with a variety of approximation methods and with the application of these methods to simple systems occurring in atomic, nuclear and solid state physics. This core material is the subject of this course.

Attendance Requirements:

Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in the examination.

Evaluation Criteria:

The overall evaluation of the students shall be for 100 marks distributed as per following scheme.

1. Mid Term Examination 25% (50 marks)
2. End Term Examination 50% (100 marks)
3. Continuous Internal Assessment 25% (50 Marks)

   Consisting of assignments/quizzes/presentation/live projects, shall contribute 20% of the total 200 marks and 5% of the marks towards internal assessment shall be on the basis of attendance.

Course Contents:

Unit 1: The overview of fundamentals of quantum mechanics (5 hours)

Schroedinger’s equation, stationary states, properties of the wavefunctions in one dimensions: degeneracy, parity, reality, number of nodes. Nature of the energy spectrum for arbitrary potential. Wave functions in position and momentum space.

Unit 2: Linear vector spaces and the Dirac notation. (5 hours)

Linear vector spaces, inner product spaces, dual spaces and the Dirac notation, linear transformations and their matrix representations, eigenvalue problems, properties of Hermitian and unitary operators, compartible and incompatible observables, generalisation to infinite dimensions. Uncertainty relation and it's proof.

Unit 3: Time independent perturbation theory (10 hours) First and second order corrections to the energy eigenvalues; First order correction to the eigenvector; Degenerate perturbation theory; Application to one-electron system – Relativistic mass correction, Spin-orbit coupling (L-S and j-j), Zeeman effect and Stark effect.

Unit 4: Variational method and the WKB aproximations (4 hours) He atom as example; First order perturbation; Exchange degeneracy; Ritz principle for excited states for Helium atom. Quantisation rule, tunneling through a barrier, discussion of α-decay.

Unit 5: Time-dependent Perturbation Theory (6 hours)

Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations — Fermi's Golden rule; Sudden and adiabatic approximations.

Unit 6: 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; Ramsauer- Townsend effect; 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.

Prescribed Textbooks:

1. *Advanced quantum mechanics*, J. J. Sakurai Wiley
2. *Principles of quantum mechanics*, R. Shankar Plenum press.
3. *Introduction to Quantum Mechanics*, D. J Griffiths, Pearson Prentice Hall, (2005).

Other Resources/Reference books:

1. *Lectures on quantum mechanics*, P. A. M Dirac, Dover edition (2001).
2. *Introductory quantum mechanics*, Richard L. Liboff Addison-Wesley publishing company.
3. *Lectures on quantum mechanics* G. Baym, Addison Wesley.
4. *Quantum Mechanics* E. Merzbacher.
5. *Quantum mechanics*, B. Bransden and C. Joachain, Pearson.

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 Equation using finite differences

- 1-D Finite Square Well potential using worksheet environment and using Scilab
- 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

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

Credits Equivalent: 2 Credits (One credit is equivalent to 10 hours of lectures / organised classroom activity / contact hours; 5 hours of laboratory work / practical / field work / Tutorial / teacher-led activity and 15 hours of other workload such as independent individual/ group work; obligatory/ optional work placement; literature survey/ library work; data collection/ field work; writing of papers/ projects/dissertation/thesis; seminars, etc.)

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

Attendance Requirements:

Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in the examination.

Evaluation Criteria:

1. Mid Term Examination at the end of 5th week for 70 marks:25% weightage
2. End Term Examination at the end of 10th week for 100 marks (about 40 marks from portions before mid-term and 60 marks from portions after mid-term): 50% weightage
3. Continuous Internal Assessment: 8 Assignments consisting of 4 or 5 problems to be solved at the end of every week other than 5th and 10th. Best 6 performances will be considered for evaluation which makes up for the remaining 25% of the total 100 marks.

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.
3) S.Y. Lee: Accelerator Physics, World scientific, 2004.
4) W.M. Stacey: Nuclear Reactor Physics, Wiley-VCH Verlag GmbH & Co.
5) H. Staneley: Principles of Charged Particle Acceleration, John Wiley & Sons.
6) H. Wiedemann: Particle Accelerator Physics I, Springer, 1999.
7) B.R. Martin: Nuclear and Particle Physics, John Wiley & Sons Ltd. 2006.
8) Particle Data Group

Computational Physics Laboratory

Course Code: PAS 427 Course Type: Core Open
Course Credit: 2

Statistical Mechanics Simulations:

Worksheet based Simulations:

Lab 1: Microstates, Macrostates and Steady-state equllibrium
Lab 2: Ergodic Hypothesis Demonstration

Simulations in Scilab:

Lab 3: Boltzmann Distibution: P(E) vs E

Lab 4: Boltzmann Speed Distribution and Maxwell's velocity distribution

Lab 5: Joule's Expansion and Entropy

Quantum Mechanics Simulations:

Lab 6: Solving the Time-Dependent Schrodinger Equation and obtaining the spreading of Gaussian wavepacket

Lab 7: Studying the Scattering of Gaussian wavepacket

Lab 8: Scattering from a step potential and a barrier potential

Computational Physics

Course Code: PAS 428 A Course Type: Core Compulsory
Course Credit: 4

Course Contents:

Unit 1: Ordinary Differential Equations: (8 hours)

- Euler method, Application to Radioactivity, Air drag and Projectile motion
- Euler-Cromet Method, Application to SHO
- Predictor-corrector method (Heun's) method, Application to Damped Harmonic Osicllator
- Second order Runge-Kutta method, Application to Forced Oscillations
- Study of Panetary motion
- Higher-order Runge-Kutta method; Application to Coupled Oscillations

Unit 2: Partial Differential Equations: (8 hours)

- Finite Difference methods: Elliptic Equations- Laplace equation, solution techniques and boundary conditions;
- Parabolic Equations- Heat Conduction Equation, explicit and implicit methods
- Crank-Nicholson Method; Application to Schrodinger equation.
- Finite Element Method: General approach and applications in One-dimension;
- Application to problems in Electromagnetics.

Unit 3: Random Variables and Random Processes: (4 hours)

- Random variables, several random variables; Statistical averages, function of a random variable, moments, characteristic function, joint moments; Transformation of random variables; Sequences of random variables; central limit theorem (without proof);
- Random processes; Stationarity; Mean, correlation and covariance functions; autocorrelation function and properties , cross-correlation functions; Ergodicity; Power spectral density; Gaussian process and its properties;

Unit 4: Random Processes and Monte-Carlo Methods: (6 hours)

- Random number generation-uniform and non-uniform distributions;
- Monte Carlo Integration- Hit and miss, Sample mean integration,
- Metropolis Method;
- Computer "Experiments" - applications of Monte-Carlo methods to problems in physics;
- Variational Monte-Carlo tecnique: Application to solving for the ground state of quantum mechanical systems in 1D and 2D

Unit 5: Fast Fourier Transforms and Spectral Methods: (6 hours)

- Discrete Fourier Transform,

- Fast Fourier Transform,
- Sande Tukey Algorithm
- Pseudospectral technique to solve the Schroedinger equation
- Application to study few 1D potentials

Theoretical Nuclear Physics

Course Code: PAS 527 Course Type: Elective Specialization
Credits: 4

Course Objectives: The course is designed to study the following:

1. Interaction of nuclear radiation like charged particles, neutrons, gamma and positron with matter and how these radiations are detected.
2. Study of decay laws, theory and use in the structure exploration of nuclei.
3. Nuclear reactions, kinematics, reaction cross-sections, different types and theories developed.
4. Nuclear Fission, characteristics and applications.
5. Basic fusion process it characteristics, solar fusion etc.

Course Contents:

Unit 1: Interaction of nuclear radiation with matter ` (10 hours)

- Interaction of charged particles with matter
- Interaction of neutrons with matter: energy loss and energy distribution after collision
- Interaction of gamma radiation with matter: attenuation of gamma rays, Compton Effect, photoelectric effect and pair production.
- Interaction of positron with matter
- Detection of nuclear radiation

Unit 2: Radioactive Decay (10 hours)

- Radioactive decay law, Quantum theory of radiative decays, production and decay of radioactivity, Growth of Daughter activities.
- Alpha decay: energetic, decay constant, hindrance factors, alpha particle spectra
- Fermi theory of β-decay, Electron and positron energy spectra, electron capture decay, parity non conservation in β-decay, nuclear structure information from β-decay.
- Theory of γ-decay and internal conversion and nuclear structure information from γ-decay

Unit 3: Nuclear reactions (12 hours)

- Cross-sections, reciprocity theorem, Elastic scattering and method of partial waves, relationship between differential and scattering amplitude.
- Free particle, turning the potential on, scattering amplitude and elastic scattering cross-section, reaction cross-section.
- Scattering by simple potential, square well potential.

- Theory of resonance: General aspects, logarithmic derivative and cross-section, Breit-Wigner formula, R-Matrix theory.

Unit 4: Nuclear Fission and Fusion (8 hours)

- Fission: Characteristics of Fission, Energy In Fission, Fission and Nuclear Structure, Controlled Fission Reactions, Fission Reactors, Radioactive Fission Products, Fission Explosives.
- Basic fusion processes, characteristics of fusion and solar fusion.

Prescribed Text Books:

1. Introductory Nuclear Physics, K. S. Krane, John Wiley& Sons Ltd
2. An Introduction to Nuclear Physics, W. N. Cottingham, D. A. Greenwood, Cambridge University Press.
3. Elements of Nuclear Physics, Walter E. Meyerhof, McGraw-Hill Book Company.

Other Resources/Reference books:

1. Fundamentals In Nuclear Physics from Nuclear Structure to Cosmology Jean-Louis Basdevant, James Rich, Michel Spiro, Springer
2. B.R. Martin, Nuclear and Particle Physics, John Wiley& Sons Ltd.
3. R.R. Roy and B.P. Nigam, Nuclear Physics: Theory and experiment, New age International (P) limited, Publishers.

Molecular Simulations in Material Science

Course Code: PAS-552 Course Type: Elective Specialization
Course Credit: 4

Credits Equivalent: 4 Credits (One credit is equivalent to 10 hours of lectures / organised classroom activity / contact hours; 5 hours of laboratory work / practical / field work / Tutorial / teacher-led activity and 15 hours of other workload such as independent individual/ group work; obligatory/ optional work placement; literature survey/ library work; data collection/ field work; writing of papers/ projects/dissertation/thesis; seminars, etc.)

Course Objectives: This course provides an introduction to modelling and simulation approaches in material science. The course will cover systematic introduction to the theory and algorithms used to implement various approaches in solving many body problems in classically and quantum mechanically. The classical part will cover well known molecular dynamics methods and quantum mechanical part will be based upon density functional based approach. This approach is an exciting new idea that allows designing of materials with desired properties from the bottom up approach.

Attendance Requirements:

Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in the examination.

Evaluation Criteria:

1. Mid Term Examination 25% (50 marks)
   At the end of 5th week the midterm examination shall be held for duration of *two hours* and shall consist of 50 marks question paper. The question paper shall consist of three sections. Section A (10 marks) shall contain 5 to10 very short answer type questions of 2/1 marks each, all being compulsory. Section B (20 marks) shall contain 6 short answer type questions of 5 marks each, out of which students have to attempt any 4. Section C (10 marks) shall consist of 2 compulsory long answer type questions of 10 marks each. The questions in section C shall have internal choice.
2. End Term Examination 50% (100 marks)
   At the end of 10th week the end term examination shall be held for duration of *three hours* and shall consist of 100 marks question paper. The question paper shall consist of three sections. Section A (20 marks) shall contain 10 to 20 very short answer type question of 2/1 marks each, all being compulsory. Section B (40 marks) shall contain 12 short answer type questions of 5 marks each, out of which students have to attempt any 8. Section C (40 marks) shall consist of 4 compulsory long answer type questions of 10 marks each. Every question in section C shall have internal choice.
3. Continuous Internal Assessment 25% (50 Marks)
   Consisting of assignments/quizzes/presentation/live projects, shall contribute 20% of the total 200 marks i.e. (40M) and 5% of the marks (i.e. 10M) towards internal assessment shall be on the basis of attendance.

Course Contents:

Unit-1: Understanding the real materials (4 hours)

- Real solids and Hamiltonian for electrons in multiatomic system.
- Challenges for obtaining quantum mechanical solution.

- Born Oppenheimer approximation,
- Free electron and independent electron approximations

Unit-2: Schrödinger Equation for a many electron system (6 Hours)

- Challenge of electron-electron interaction and Hartree approximation
- Limitations of Hartree approximation and Slater determinant
- Hartree-Fock approximation and deriving Hartree-Fock equations equations: Variational approach,
- Ground state energy, ionization energy and Koopmans theorem. Excited states and transition energy (ignoring relaxation effects).
- Hartree Fock equations and transition energies in closed shell systems.
- Hartree-Fock-Slater and Hartree-Fock-Roothaan methods. Beyond one electron approximation.

Unit-3: Basis sets (8 hours)

- Plane waves, as basis function and their limitations
- Tight binding approximation
- Orthogonal plane wave method (OPW)
- Frozen core approximation and pseudopotential method,
- Cellular method: its successes and failures
- Muffin tin potentials, augmented plane wave method, (APW)
- Linearized augmented plane waves (LAPW).
- Slater type orbitals, Gaussian type orbitals, Numerical basis functions.

Unit-4: Electron gas (4 Hours)

- Basic elements of free electron gas, Jellium Model
- Homogeneous electron gas in Hartree-Fock approximation.
- Fully polarized ferromagnetic electron gas. Wigner crystallization.
- Electronic properties and phase diagram of homogeneous electron gas.

Unit-5: Basics of density functional theory (8 Hours)

- Basics of funcaional analysis. Orbital free density functional theory: Thomas Fermi theory.
- Hohenberg Kohn theorems.
- Kohn Sham (KS) equations.
- KS equations in Plane wave form. *k*-point sampling.
- Exchange and correlation holes, Exchange correlation functional: Local density approximation.
- Gradient correction methods: Generalised gradient approximation (GGA).
- Basic idea of meta-GGA, hyper-GGA. Band structure and density of states of some standard materials.
- DFT as Materials modelling tool. Limitations of density functional theory.

Unit 6: Fundamentals of Molecular dynamics simulations (10 hours)

- Molecular Dynamics Methodology-Force Field,
- Molecular dynamics potentials, force calculation,
- Long Range Forces and cut off radius
- Integrating Algorithms
- Boundary conditions, Periodic Box and Minimum Image Convention, Non Bonded Interaction
- Temperature Control and thermostats in molecular dynamics

- Pressure Control and Barostats in molecular dynamics
- Estimation of Pure Component Properties
- Radial Distribution Function and its significance

- Molecular Dynamics Packages.

Prescribed text books:

1. *Solid State Physics*, Guiseppe Grosso and Guiseppe Pastori Parravicini, Academic Press

2. *Methods Of Electronic Structure Calculations*, Springborg Michael, John Wiley and Sons

3. *The Art of Molecular Dynamic Simulations*, D. C. Rapaport, Cambridge University Press

Other Resources/Reference books:

1. *Introduction to Computational Chemistry*, Frank Jensen, 2nd edition, John Wiley and Sons Ltd.
2. *Solid State Physics*, Guiseppe Grosso and Guiseppe Pastori, Academic Press.
3. *Solid State Physics*, Neil W. Ashcroft and N. David Mermin, Cengage Learning India Pvt Ltd.
4. *The Electronic Structure Of Solids*, B.R. Coles and A. D. Caplin, Edward Arnold publishers
5. *Electronic Structure: Basic Theory And Practical Methods*, Richard M. Martin, Cambridge University press
6. *Introduction To Computational Physics*, T. Pang, Cambridge University press
7. *A Bird's-Eye View of Density-Functional Theory*, Klaus Capelle, arXiv:cond-mat/0211443 (2006)
8. *The Density Functional Formalism, Its Applications And Prospect*, R.O. Jones and O. Gunnarsson, Reviews of Modern Physics, Vol. 61, No. 3, July 1989
9. *Iterative Minimization Techniques For Ab Initio Total-Energy Calculations: Molecular Dynamics And Conjugate Gradients*, M.C. Payne et al. Reviews of Modern Physics, Vol. 64, No. 4, October 1992
10. Nobel Lecture: *Electronic Structure Of Matter-Wave Functions And Density Functional*, W. Kohn, Rev. Mod. Phys., Vol. 71, No. 5, October 1999
11. *The ABC of DFT*, Kieron Burke and friends, "*http://chem.ps.uci.edu/~kieron/dft/book/*"

Nanomaterials & Technology

Course Code: PAS 516

Course Type: Elective Open

Course Credit: 2

Course Objectives:

- Applications in solving problems of interest to physicists.
- Explore the potential application of physics at nanoscale regime.

Course Contents:

Unit 1: Nanoscale Systems (8 hours)

- Nanostructures and Nanoscale Devices
- Quantization in Nanostrctures
  - Quantization in Heterojunction Systems (Quantum Well)
  - Lateral Confinement (Quantum Wires and Quantum Dots)
  - Electronic States in Quantum Wires and Dots
- Magnetic Field Effects in Quantum Confined Systems
- Transmission in Nanostructures
  - Tunnelling in Planar Barrier Structures
  - Current in Resonant Tunnelling Diodes
- Landauer Formula &The Multi-channel Case

Unit 2: Synthesis of Nanomaterials (6 hours)

- Top-down and Bottom-up Approach
  - Zero-dimensional nanostructures (nanoparticles)
  - One-dimensional nanostructures (nanowires)
  - Two-dimensional nanostructures (thin films)
  - Special nanomaterials (fullerene, carbon nanotube, graphene)
- Physical Vapour Deposition (PVD)
  - Pulsed Laser Deposition
  - Thermal Evaporation
  - E-beam Evaporation
  - DC & RF Sputtering
  - Molecular Beam Epitaxy (MBE)
- Chemical vapour deposition (CVD)
- Lithography
  - Photolithography
  - Electron Beam Lithography (EBL)
  - Focussed Ion Beam

Unit 3: Characterization of Nanomaterials (6 hours)

- X-Ray Diffraction
- Optical Microscopy
- Electron Microscopy
  - Scanning Electron Microscopy

    - Transmission Electron Microscopy
- Scanning Probe Microscopy
    - Atomic Force Microscopy
    - Scanning Tunnelling Microscopy

Other Resources/References books:

1. Transport in Nanostructures, D. K. Ferry, Cambridge University Press (2009).
2. Principals of Nano-optics, L. Novotny and B. Hecht, Cambridge University Press (2006).
3. Quantum Transport: Atom to Transistor, S. Datta, Cambridge University Press (2005).
4. Nanostructures & Nanomaterials, G. Cao, World Scientific (2015).
5. The Science and Engineering of Microelectronic Fabrication, S. A. Cambell, OUP (2001).
6. E. N. Kaufmann, Characterization of Materials, Wiley (2003).

Project

Course Code: PAS 548 Course Type: Élective

Spécialisation Course Credit: 4

To be Developed

Department of Physics and Astronomical Science
Central University of Himachal Pradesh
Shapur Campus

Program Specific Outcomes (PSO),

Program Outcomes (PO),

Course Outcomes (CO) & Course Contents

of

Bachelor of Science in Physics (Honours)

B. Sc. (Honours) Physics

School of Physical and Material Sciences

Semester-Wise Distribution of Courses

Semester	Type of Courses	Credits	Total Credits
I	Major Courses	08	20
	IDC Minor Course	04	
	Lab/field	02	
	Vocational/Skill	02	
	IKS	04	
II	Major Courses	08	20
	IDC Minor Courses	04	
	Lab/field	02	
	Vocational/Skill	04	
	Indian Language	02	
III	Major Courses	04	20
	Minor Courses	04	
	Lab/Field	04	
	Vocational/Skill	08	
	Community Connect	04	
IV	Major Courses	08	20
	Minor Courses	04	
	Lab/Field	02	
	Vocational/Skill	02	
	Environmental Studies	04	
V	Major Courses	08	20
	Minor Courses	02	
	Vocational/Skill	02	
	Swachh Bharat	02	
	Environmental Studies	02	
	Community Connect	04	

	Subject Internship/ Innovation		
VI	Major Courses	08	**20**
	Minor Courses	04	
	IKS	04	
	Cultural Exchange	04	
VII	Major Courses	04	**20**
	Minor Courses	04	
	Lab/field	02	
	Advanced Knowledge in Discipline	10	
VIII	Major Courses	04	**20**
	Minor Courses	02	
	Lab/field	02	
	Advanced Knowledge in Discipline	08	
	Research Work	04	
Total			**160**

Program Specific Outcomes of Bachelor of Science in Physics (Honours)

The B Sc (Honours) in Physics programme at Department of Physics and Astronomical Science, Central University of Himachal Pradesh provides a broader framework which helps to create an academic base that eventually strengthen the students to understand the basic laws of physics and its imperative applications in various physical domains. The programme is designed and implemented in such a way that helps the students acquire scientific attitude, develop critical and analytical skills and research oriented aptitude along with understanding the conventional existing knowledge base in the subject. Apart from the main subjects of the programme, the students has options to relate the knowledge gained and connect it to the society, in general, through community connect program of the department. The programme is designed in such a way that it reflects all the basic ingredients of the National Education Policy (NEP 2020) in its true spirit. During the fourth year of the programme the students are exposed to the advanced level topics of the course at par with the first year of post graduation helping them understand the intricacies of the field to decide the career option in higher studies. Furthermore, during the research project in the final year the students are trained to acquire additional skills like analytical, numerical and experimental skills helping them prepare for the research career ahead. In addition, the students are expected to acquire rational thinking and critical approach which will help them beyond the subject lines in other allied areas whether it is in education or research sector or in social sector, in general. Some of the outcomes, identified by the department are listed below:

PSO1: The students will understand disciplinary knowledge and be able to apply it to real physical system with an approach to extend it to other similar domains.

PSO2: After the completion of this programme, the students will develop the knowledge and general competence required to pursue higher studies in the subject including education and research.

PSO3: The course as a whole opens up several career doors for the students interested in various areas of science at technology in private, public and government sectors.

PSO4: Other than the subject specific quality outcomes, the student, in general, will acquire a good sense of inclusive responsibility of preserving our environment through active participation in courses like Swachh Bharat and Environmental studies.

Program Outcomes of Bachelor of Science in Physics (Honours)

PO1: The students would gain substantial knowledge in various branches of physics such as classical and quantum mechanics, mathematical physics, statistical mechanics, condensed matter physics, astronomy and astrophysics and nuclear and particle physics.

PO2: The research project during the final year is intended to develop a problem solving aptitude through which the student is encouraged to apply the acquired knowledge to real physical systems.

PO3: The students will develop analytical and experimental skills through theory and laboratory sessions.

PO4: Recognize the importance of mathematical modeling simulation and computing, and the role of approximation and mathematical approaches to describing the physical world.

Major Courses

Mechanics

Course Code: PAS5101 **Course Type: Major**
Credit: 4
Course Objectives:
The objective of this course is to provide:

- a coherent introduction to mechanics. The study of the dynamical behavior of the body under the influence of external forces will occupy the centre stage of this course.
- It is intended to take the students to the level where they can appreciate Lagrangian and Hamiltonian formulations of classical mechanics.
- exposure to the language that is very useful in physics i.e. vectors and coordinate systems.
- develop basic theoretical framework to understand Collision theory and Rotational dynamics of the rigs body.
- to understand non-inertial frames of references and emergence of fictitious forces as a consequence of the non-inertial nature.
- to study motion under central force.
- an elementary introduction to special theory of relativity and its consequences.

Course Outcomes: After going through the course, the student should be able to

CO1: Understand the role of vectors and coordinate systems in Physics.
CO2: Write the expression for the moment of inertia about the given axis of symmetry for different uniform mass distributions.
CO3: Explain the conservation of energy, momentum, angular momentum and apply them to basic problems.
CO4: Understand the analogy between translational and rotational dynamics, and application of both motions simultaneously in analyzing rolling with slipping.
CO5: Apply Kepler's law to describe the motion of planets and satellite in circular orbit.
CO6: Explain the phenomena of simple harmonic motion and the properties of systems executing such motions.
CO7: Describe how fictitious forces arise in a non-inertial frame, e.g., why a person sitting ina merry-go-round experiences an outward pull.
CO8: Describe special relativistic effects and their effects on the mass and energy of a moving object.

Course Contents

Unit-1: Fundamentals of Dynamics: Reference frames. Inertial frames, Review of Newton's Laws of Motion. Galilean transformations.Galilean invariance. Momentum of variable mass system: motion of rocket. Motion of a projectile in uniform gravitational field.Dynamics of a system of particles. Centre of Mass, Principle of conservation of momentum, Impulse.

(7 hours)

Unit-2: Work and Energy: Work and Kinetic Energy Theorem. Conservative and nonconservative forces. Potential Energy.Energy diagram.Stable and unstable equilibrium.Elastic potential energy. Force as gradient of potential energy. Work & Potential energy.Work done by non-conservative forces.Law of conservation of

Energy. **(5 hours)**

Unit-3: Collisions: Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.

(4 hours)

Unit-4: Rotational Dynamics: Angular momentum of a particle and system of particles. Torque.Principle of conservation of angular momentum.Rotation about a fixed axis.Moment of Inertia.Calculation of moment of inertia for rectangular, cylindrical and spherical bodies.Kinetic energy of rotation.Motion involving both translation and rotation.

(12 hours)

Unit-5: Elasticity: Review of relation between Elastic constants. Twisting torque on a Cylinder or Wire (only qualitative discussion).

(2 hours)

Unit-6: Gravitation: Law of gravitation. Gravitational potential energy. Inertial & gravitational mass. Potential and field due to spherical shell and solid sphere

(3 hours)

Unit-7: Central force Motion: Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws.Satellite in circular orbit & applications. **(6 hours)**

Unit-8: Oscillations: Review of SHM Simple Harmonic Oscillations. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor.

(7 hours)

Unit-9: Non-Inertial Systems: Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems.Centrifugal force.Coriolis force and its applications.

(4 hours)

Unit-10: Special Theory of Relativity: Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity.Lorentz Transformations.Simultaneity and order of events.Lorentz contraction.Time dilation.Relativistic transformation of velocity, frequency and wave number.Relativistic addition of velocities.Variation of mass with velocity.Massless Particles.Mass-energy Equivalence. Relativistic Doppler effect. Relativistic Kinematics.Transformation of Energy & Momentum.

(10 hours)

Prescribed Text Books:

1. Mechanics, D. S. Mathur, S. Chand and Company Limited, 2000.
2. Mechanics, C. Kittle, W. D. Knight and M. A. Ruderman, Berkeley Physics Course,

McGraw-Hillbookcompany.
3. An introduction to mechanics, D. Kleppner, R. J. Kolenkow, 1973, McRwaw-Hill book company.
4. Analytical Mechanics, Satish K. Gupta, Modern Publisher.

Suggested AdditionalReadings:

1. Physics, Resnick, Halliday and Walker, Wiley.
2. Analytical Mechanics, G. R. Fowles and G. L. Cassiday, 2005, Cengage learning.
3. Feynman Lectures, Vol. I, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson education.
4. Theoretical mechanics, M. R. Spiegel, 2006, Tata McGraw-Hill.

Course Articulation Matrix of PAS5101- Mechanics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	2	1	2	3	1
CO2	3	1	2	2	1	3	1	1
CO3	2	1	2	3	2	3	2	1
CO4	3	1	2	3	3	3	1	1
CO5	2	1	2	3	2	2	2	1
CO6	3	1	2	2	2	3	3	1
CO7	3	1	2	2	1	3	3	1
CO8	3	1	2	1	2	1	2	1

1: Partially related
2: Moderately related
3: Strongly related

Mathematical Physics- I

Course Code: PAS5102 **Course Type: Major**
Credit: 4

Course Objectives: The Mathematical physics and basic mathematics is an essential tool required for understanding physics. The main objective of the course is to:

- recapitulate and introduce the students to some techniques of calculus of function,
- Algebra of scalar and vector fields.
- Calculus of scalar and vector fields.

Course Outcomes: The student shall be able to use

CO1: Techniques of differentiation and integration of functions.
CO2: Various techniques of vector addition and multiplication.
CO3: Differentiate vector functions and interpret them.
CO4: Solve integration of vector functions on curves, surfaces and volumes.
CO5: Higher mathematical concepts essential in physics.

Course Contents

Unit1: Differential calculus: Recapitulation: Functions, plotting of curves; Limits and continuity, rigorous definition; Differentiation. Approximations: Taylor and binomial series. Functions of several variables, plotting of multivariable functions, rules of differentiation. **(15 Lectures)**

Unit 2: Integral calculus: Integrations of the form : $\int dx/(a + b \cos x)$, $\int (n \sin x + p \cos x)/(l \sin x + m \cos x)dx$, Integration of rational functions.
Evaluation of definite integrals, Reduction formulae, Improper integrals, convergence tests, Beta and gamma functions. **(12 lectures)**

Unit 3: Vector calculus:

Recapitulation of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations.Vector product, Scalar triple product and their interpretation in terms of area and volume respectively.Scalar and Vector fields.

Vector Differentiation: Directional derivatives and normal derivatives.Gradient of a scalar field and its geometrical interpretation.Divergence and curl of a vector field.Del and Laplacian operators.Vector identities.

Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian.Notion of infinitesimal line, surface and volume elements.Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications.

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems. **(30 lectures)**

Unit4: Dirac Delta function and its properties:

Definition of Dirac delta function.Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function. **(3 lectures)**

Text books:

1. Differential calculus: B. Das and B.N. Mukherjee, U.Dhar publishers.

2. Integral calculus: B. Das and B.N. Mukherjee, U Dhar publishers.

3. Vector analysis: M. Spiegel, Schaum series.

4. Mathematical methods for physicists, G. Arfken, Academic press.

Reference Books:

1. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press.

2. Vector and tensor analysis: H. Lass, McGraw Hill.

3. Introduction to electrodynamics: D. J Griffiths, Prentice Hall.

4. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India

5. Essential Mathematical Methods, K.F.Riley&M.P.Hobson, 2011, Cambridge Univ. Press.

Course Articulation Matrix of PAS5102- Mathematical Physics-I

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	3	1	2	3	1
CO2	3	1	2	3	1	3	1	1
CO3	2	1	2	3	2	3	2	1
CO4	3	1	2	3	3	3	1	1
CO5	3	1	2	3	2	2	2	1

1: Partially related
2: Moderately related
3: Strongly related

Electricity and Magnetism

Course Code: PAS5201 **Course Type: Major**
Credit: 4

Course objectives:

- Understand the basic concepts of electric and magnetic fields.
- Understand the concept of conductors, dielectrics, inductance and capacitance.
- Gain knowledge on the nature of magnetic materials.
- Understand the concept of static and time varying fields.
- Gain knowledge on electromagnetic induction and its applications
- Gain knowledge on EM waves, propagation and their properties.
- Ability to use Maxwell's equations in calculations featuring: both free and stationary electromagnetic waves.

Course Outcomes:

CO1: Students should among other things have knowledge about Fundamental laws and concepts in electricity and magnetism, especially with regard to Maxwells laws - Electrical circuits and the most common components in such: resistors, capacitors, and inductors.

CO2: The properties of static electric and magnetic fields and how they arise - The properties of simple, time-dependent electric and magnetic fields and what kind of physical phenomena they generate.

CO3: Electromagnetic waves and their properties - Important historical experiments in the field of electricity and magnetism. The candidate should among other things be able to: - Analyze different problems in electromagnetism using mathematical methods involving vectors and simple differential and integral calculus, both analytically and numerically .

CO4: Analyze electric circuits to compute currents and voltage drops, both in stationary and time-dependent situations - Solve Maxwells equations for simple systems. Describe the nature and the characteristic properties of electric and magnetic fields, and the interrelationship between these fields.

CO5: Understand the mathematics of electric and magnetic fields in terms of conservative and non-conservative fields, and scalar and vector potentials.
Be able describe the effect of these fields on electric charges and magnetic dipoles.

CO6: Understand how moving charges and changing currents give rise to electromagnetic radiation and be able to describe the nature and properties of electromagnetic waves

Course Contents

Unit1: Electric Field and Electric Potential
Electric field: Electric field lines. Electric flux.Gauss' Law with applications to chargedistributions with spherical, cylindrical and planar symmetry.
(6 Lectures)

Unit 2: Conservative nature of Electrostatic Field. Electrostatic Potential. Laplace's and Poisson equations.The Uniqueness Theorem.Potential and Electric Field of a dipole. Force and Torque on a dipole. **(6 Lectures)**

Unit 3: Electrostatic energy of system of charges. Electrostatic energy of a charged sphere.Conductors in an electrostatic Field. Surface charge and force on a conductor.Capacitance of a system of charged conductors.Parallel-plate capacitor.Capacitance of an isolated conductor. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere. **(10 Lectures)**

Unit4: Dielectric Properties of Matter: Electric Field in matter. Polarization, Polarization Charges.Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss' Law in dielectrics. **(8 Lectures)**

Unit 5: Magnetic Field: Magnetic force between current elements and definition of MagneticFieldB. Biot-Savart's Law and its simple applications: straight wire and circular loop.Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with ElectricDipole).Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field.

(9 Lectures)

Unit 6: Magnetic Properties of Matter: Magnetization vector (M). Magnetic Intensity(H). Magnetic Susceptibility and permeability.Relation between B, H, M. Ferromagnetism.B-H curve and hysteresis. **(4 Lectures)**

Unit 7: Electromagnetic Induction: Faraday's Law. Lenz's Law.Self Inductance and MutualInductance.Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction toMaxwell's Equations. Charge Conservation and Displacement current. **(6 Lectures)**

Unit 8: Electrical Circuits: AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactanceand Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit.

(5 Lectures)

Unit 9: Network theorems: Ideal constant-voltage and constant-current Sources. Review ofKirchhoff's Current Law & Kirchhoff's Voltage Law.Mesh & Node Analysis.Theventheorem, Norton theorem, Superposition theorem, Reciprocity Theorem, Maximum Power Transfer theorem.Applications to dc circuits.

(6 Lectures)

Reference Books:

1. Electricity, Magnetism & Electromagnetic Theory, S.Mahajan and Choudhury,2012, Tata McGraw
2. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
3. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
4. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
5. Electricity and Magnetism, J.H.Fewkes&J.Yarwood. Vol.I, 1991, Oxford Univ. Press.

Course Articulation Matrix of PAS5201- Electricity and Magnetism

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	2	1	2	3	1
CO2	2	1	2	2	1	3	1	1
CO3	2	1	2	2	2	3	2	1
CO4	3	1	2	2	3	3	1	1
CO5	3	1	2	2	2	2	2	1
CO6	3	1	2	2	2	3	3	1

1: Partially related
2: Moderately related
3: Strongly related

Mathematical Physics II

Course Code: PAS5202 **Course Type: Major**
Credit: 4

Course Objectives: Mathematical physics and basic mathematics is an essential tool required for understanding physics. The main objective of the course is

- Introducesome techniques of ordinary differential equations
- Solve ordinary differential equations with constant and variable coefficients.
- Solve partial differential equations arising in various topics of physics.

Course Outcomes: The student shall be able to

CO1: Solve differential equation of various types arising in physics and mathematics.
CO2: Develop techniques to solve complicated equations using the series solution method.
CO3: Understand the importance of Fourier spaces and analyse functions accordingly.
CO4: Solve equations of mathematical physics in various coordinate systems.

Course Contents

Unit 1: Fourier expansion of functionsFourier Series: Periodic functions.

Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only).Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients.Complex representationof Fourier series.Expansion of functions with arbitrary period.Expansion of non-periodic functions over an interval.Even and odd functions and their Fourierexpansions.Application.Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

(14 Lectures)

Unit 2: Differential equations with constant coefficients:

First Order Differential Equations and Integrating Factor. Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution.Statement of existence and Uniqueness Theorem for Initial Value Problems.Particular Integral. **(10 Lectures)**

Unit 3: Frobenius Method and Special Functions:

Singular Points of Second Order Linear Differential Equations and their importance.Frobenius method and its applications to differential equations.Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations.Expansion of function in a series of Legendre Polynomials.

Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions and Orthogonality. **(24 Lectures)**

Unit 4: Partial Differential Equations:Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.

(12 Lectures)

Text books:

1. Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier.
2. Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.
3. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
4. Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
5. Partial Differential Equations for Scientists & Engineers, S.J. Farlow, 1993, Dover Pub.
6. Mathematical methods for Scientists & Engineers, D.A. McQuarrie, 2003, Viva Books

Reference Books:

1. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press.
2. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India
3. Essential Mathematical Methods, K.F.Riley&M.P.Hobson, 2011, Cambridge Univ. Press.

Course Articulation Matrix of PAS5202- Mathematical Physics-II

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	3	1	2	3	1
CO2	3	1	2	3	1	3	1	1
CO3	2	1	2	3	2	3	2	1
CO4	3	1	2	3	3	3	1	1

1: Partially related
2: Moderately related
3: Strongly related

Thermal and Statistical Physics

Course Code: PAS6101 **Course Type: Major**
Credit: 4

Course Objectives: This course aims to provide a good platform to graduation students to understand the thermodynamics and statistical physics.

Course Outcomes: After completing the course satisfactorily, a student will be able:

CO1: To investigate the effectiveness of energy conversion process in mechanical power generation for the benefit of mankind.

CO2: To understand Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency

CO3: To understand the four postulates, including definitions of state variables and the entropy. To understand the "seminal problem" and the "entropy maximum" principle.

Course Contents

Unit 1: Zerothand First Law of Thermodynamics

Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient.

(8 Lectures)

Unit 2: Second Law of Thermodynamic

Reversible and Irreversible process with examples.Conversion of Work into Heat and Heat into Work.Heat Engines.Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale. **(10 Lecture)**

Unit 3: Entropy

Concept of Entropy, Clausius Theorem.Clausius Inequality, Second Law of Thermodynamics in terms of Entropy.Entropy of a perfect gas.Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe.Entropy Changes in Reversible and Irreversible Processes.Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamic.Unattainability of Absolute Zero. **(7 Lectures)**

Unit 4: Thermodynamic Potentials

Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications.Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, ClausiusClapeyron Equation and Ehrenfest equations.

(7 Lectures)

Unit5: Maxwell's Thermodynamic Relations

Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1)

ClausiusClapeyron equation, (2) Values of Cp-Cv, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Vander Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process. Kinetic Theory of Gases.

(7 Lectures)

Unit6: 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, SackurTetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations.

(10 Lectures)

Unit7: Classical Theory of Radiation:

Properties of Thermal Radiation.Black body Radiation.Pure temperature dependence.Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure.Wien's Displacement law. Wien's Distribution Law.

(7 Lectures)

Unit8: 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. **(4 Lectures)**

Text books:

1. Thermal physics S.C Garg/ RM Bansal / CK Ghosh
2. E. Guha, Basic thermodynamics, Narosa , New Delhi, 2000
3. Thermodynamic kinetic theory , and statistical thermodynamic ,Sears. Salinger

Course Articulation Matrix of PAS6101- Thermal and Statistical Physics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	2	1	2	3	1
CO2	2	1	2	2	1	3	1	1
CO3	2	1	2	2	2	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Mathematical Physics III

Course Code: PAS6102 **Course Type: Major**
Credit: 2

Course Objectives: Mathematical physics and basic mathematics is an essential tool required

for understanding physics. The main objective of the course is to introduce you to some techniques of

- Algebra of complex functions
- Calculus of complex functions a single variable.
- introduce some techniques of integral equations.
- Fourier integrals of functions of single variables.
- Laplace integrals of functions of single variables.

Course Outcomes: The student shall be able to :

CO1: Develop techniques to solve complex variables to solve equations of physics.
CO2: Understand poles and singularities of various functions.
CO3: Solve integrals having complicated functions and singularities.
CO4: Differential equations of functions with a definite boundedness.
CO5: Equations of physics involving boundary conditions of Dirichlet and Neumann type.
CO6: Various equations useful in electrical circuits and wave theory.

Course Contents

Unit 1: Complex numbers and their properties:

Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. **(3 Lectures)**

Unit 2: Analytic functions of complex variables

Functions, limits, continuity, derivatives.Cauchy- Riemann equations, Analytic functions, Hamonic functions.

Elementary functions of complex variables: Exponential, Logarithmic, Trigonometric. **(5 Lectures)**

Unit 3: Integrals

Contours, and contour integrals, Cauchy and Cauchy- Goursat theorems, Simply and multiply connected domains, Cauchy integral formula. Liouville and maximum modulus theorems. **(7 Lectures)**

Unit 4: Series and classification of singularities

Series and their convergence, Taylor's theorem, Laurent's theorem.Power series. Classification of singularities, isolated singularities, poles and branch points, order of singularity, branch cuts. **(10 Lectures)**

Unit 5: Residue theorem and its applications

Residue theorem, Jordan's lemma, Evaluation of improper and definite integrals. Indented paths around a branch point, integrals along branch cuts.

(5 Lectures)

Unit 6: Fourier Integrals:

Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric,Gaussian, finite wave train & other functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations. **(15 Lectures)**

Unit 7: Laplace integrals

Laplace Transforms: Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits. **(10 Lectures)**

Unit 8: Integral equations

Integral equations: Volterra and Fredholm types, and solution techniques.

(5 Lectures)

Text books:

1. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
2. Mathematics for Physicists, P. Dennery and A.Krzywicki, 1967, Dover Publications
3. Complex Variables, A.S.Fokas&M.J.Ablowitz, 8th Ed., 2011, Cambridge Univ. Press
4. Complex Variables and Applications, J.W. Brown & R.V. Churchill, 7th Ed. 2003, Tata McGraw-Hill.
5. Complex analysis: M. R. Speigel, Schaum ,McGraw Hill.

Reference Books:

1. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press.
2. First course in complex analysis with applications, D.G. Zill and P.D. Shanahan, 1940, Jones & Bartlett

Course Articulation Matrix of PAS6102- Mathematical Physics-III

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	3	1	2	3	1
CO2	3	1	2	3	1	3	1	1
CO3	2	1	2	3	2	3	2	1
CO4	3	1	2	3	3	3	1	1
CO5	3	1	2	3	3	3	2	1
CO6	3	1	2	3	3	2	2	1

1: Partially related
2: Moderately related
3: Strongly related

Waves and Optics

Course Code: PAS6201 **Course Type: Major**
Credit: 4

Course Objectives: The emphasis of this course is to introduce students to conceptsand phenomena related to oscillatory systems. The fundamentals of such oscillatory systems are applied to understanding of waves and optics.

Course Outcomes: After completing this course, the students will be able to understand:

CO1: Simple harmonic oscillations and their origin

CO2: Superposition of oscillatory quantities and their applications

CO3: Wave equation and its significance

CO4: How the superposition principle play crucial role in explaining many optical phenomenon such as interference, diffraction.

CO5: Fundamentals of holography

Course contents

Unit 1: Superposition of Collinear Harmonic oscillations: Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences.
(6 Lectures)

Unit 2: Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods.Lissajous Figures with equal an unequal frequency and their uses. **(2 Lectures)**

Unit 3: Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves.Wave Equation.Particle and Wave Velocities.Differential Equation.Pressure of a Longitudinal Wave.Energy Transport.Intensity of Wave. Water Waves: Ripple and Gravity Waves.
(4 Lectures)

Unit 4: Velocity of Waves: Velocity of Transverse Vibrations of Stretched Strings. Velocity of Longitudinal Waves in a Fluid in a Pipe.Newton's Formula for Velocity of Sound.Laplace's Correction. **(6 Lectures)**

Unit 5: Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends.Analytical Treatment.Phase and Group Velocities.Changes with respect to Position and Time.Energy of Vibrating String.Transfer of Energy.Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment.Longitudinal Standing Waves and Normal Modes.Open and Closed Pipes.Superposition of N Harmonic Waves. **(7 Lectures)**

Unit 6: Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle.Temporal and Spatial Coherence. **(3 Lectures)**

Unit 7: Interference:
Division of amplitude andwavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: Measurement of wavelength and refractive index.
(9 Lectures)

Unit 8: Interferometer:

Michelson Interferometer-(1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, and (5) Visibility of Fringes. Fabry-Perot interferometer. **(4 Lectures)**

Unit 9: Diffraction:

Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula. (Qualitative discussion only) **(2 lectures)**

Unit 10: Fraunhofer diffraction:

Single slit. Circular aperture, Resolving Power of a telescope.Double slit. Multiple slits. Diffraction grating.Resolving power of grating. **(8 Lectures)**

Unit 11: Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave.Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel's Integral, Fresnel diffraction pattern of a straight edge, a slit and a wire. **(7 Lectures)**

Unit 12: Holography: Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves.Point source holograms. **(3 Lectures)**

Text books:

1. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, (2007), Tata McGraw-Hill
2. The Physics of Waves and Oscillations by N.K. Bajaj (1988), Tata McGraw-Hill

Reference texts:

1. Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, (2011) R. Chand Publications
2. Principles of Optics, Max Born and Emil Wolf, 7thEdn., (1999) Pergamon Press
3. Fundamentals of Optics, F.A. Jenkins and H.E. White, (1981) McGraw-Hill
4. Optics, AjoyGhatak (2008) Tata McGraw Hill
5. Vibrations and Waves, A. P. French (1987) CBS Pub. & Dist.
6. Vibrations and Waves, Banjamin Crowell, Light & Matter Series (www.lightandmatter.com)
7. Fundamentals of Waves & Oscillations K. Uno Ingard (1988) Cambridge University Press

<u>Course Articulation Matrix of PAS6201- Waves and Optics</u>

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	2	3	2	3	1
CO2	2	1	2	2	3	3	3	1
CO3	2	1	2	2	2	3	2	1
CO4	3	1	2	2	3	3	3	1

CO5	3	1	2	2	3	3	3	1

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Quantum Physics and Applications

Course Code: PAS7101 **Course Type: Major**
Credit: 4

Course Objective: This course aimed at giving foundation course in Quantum Mechanics and its application

Course Outcomes: This gives details about the Quantum Mechanics and Application courses offered for Bachelor of Science (BSc) course in the department of Physics and Astronomical Sciences. After getting this course the student will be acquainted with the basic principles of Quantum Mechanics and its applications:

CO1: Have gained a clear knowledge about wave properties of particles,De Broglie waves and its implications on theuncertainty principle.

CO2: Study the Bohr Atom model in detail and understand about atomic excitations

CO3: Have grasped the idea of Wave Mechanics and gain the concept of eigen values, eigen functions and learn the basic postulates of quantum mechanics

CO4: :To find solution to Schrödinger's equation for many systems such as particle in a box, Hydrogen Atom and familiarize with different quantum numbers.

Course contents

Unit 1: Time dependent Schrodinger equation:

Time dependent Schrodinger equation and dynamical evolution of a quantum state; Propertiesof Wave Function.Interpretation of Wave Function Probability and probability current densitiesin three dimensions; Conditions for Physical Acceptability of Wave Functions.Normalization.Linearity and Superposition Principles.Eigenvalues and Eigenfunctions.Position, momentumand Energy operators; commutator of position and momentum operators; Expectation values ofposition and momentum.Wave Function of a Free Particle.

(6 Lectures)

Unit 2: Time independent Schrodinger equation:

Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction asa linear combination of energy eigenfunctions; General solution of the time dependent Schrodingerequation in terms of linear combinations of stationary states; Application to spread of Gaussianwave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentumspace wavefunction; Position-momentum uncertainty principle.

(10 Lectures)

Unit 3: General discussion of bound states in an arbitrary potential:

Continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonicoscillator-energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials;ground state, zero point energy uncertainty principle. **(12 Lectures)**

Unit 4: Quantum theory of hydrogen-like atoms:

time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator quantum numbers;Radial wave functions from Frobenius method; shapes of the probability densities for ground first excited states; Orbital angular momentum quantum numbers l and m; s, p, d,.. shells.

(10 Lectures)

Unit 5: Atoms in Electric Magnetic Fields:

Electron angular momentum.Space quantization.Electron Spin and Spin Angular Momentum.Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. **(8Lectures)**

Unit 6: Atoms in External Magnetic Fields:

Normal and Anomalous Zeeman Effect.Paschen Back and Stark Effect (Qualitative Discussiononly). **(4 Lectures)**

Prescribed Textbooks:

1. D. J. Griffiths, Introduction to Quantum Mechanics, Pearson.
2. J. L. Powel and B. Crasemann, Quantum Mechanics, Dover.
3. R. H. Dicke and J. P. Wittke, Introductions to Quantum Mechanics, Addison Wesley.
4. Arthur Beiser, Concepts of Modern Physics, McGraw Hill.
5. H. C. Verma, Quantum Physics, TBS.
6. M. Das and P. K. Jena, Introduction to Quantum Mechanics, Srikrishna Publication.

Course Articulation Matrix of PAS7101- Quantum Physics and Applications

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	3	2	3	3	3	1
CO2	2	1	2	2	3	3	3	1
CO3	2	1	3	2	2	3	2	1
CO4	3	1	2	2	3	3	3	1
CO5	3	1	2	2	3	3	3	1

1: Partially related
2: Moderately related
3: Strongly related

Astronomy and Astrophysics

Course Code: PAS7102 **Course Type: Major**
Credit: 4
Course Objectives: The prime aim of this course is to provide a pedagogical introduction to astronomy and astrophysics both on the galactic and extragalactic scale at the graduation level along with the brief introduction to astronomical techniques.

Course Outcomes:
After completing the course satisfactorily, a student will be able:
CO1: To understand the technique in observational astronomy
CO2: To understand the distance ladder in the context of the size of the Universe

CO3: Sun and stellar synthesis. Interstellar medium
CO4: Galaxies and their morphology
CO5: Smooth and clumpy universe. The basic mathematical machinery of the background Universe.

Course Contents

Unit 1: Astronomical Scales: Astronomical Distance, Mass and Time, Scales, Brightness, Radiant Flux and Luminosity, Measurement of Astronomical Quantities Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature. Basic concepts of positional astronomy: Celestial Sphere, Geometry of a Sphere, Spherical Triangle, Astronomical Coordinate Systems, Geographical Coordinate Systems, Horizon System, Equatorial System, Diurnal Motion of the Stars, Conversion of Coordinates. Measurement of Time, Sidereal Time, Apparent Solar Time, Mean Solar Time, Equation of Time, Calendar. Basic Parameters of Stars: Determination of Distance by Parallax Method; Brightness, Radiant Flux, and Luminosity, Apparent and Absolute magnitude scale, Distance Modulus; Determination of Temperature and Radius of a star; Determination of Masses from Binary orbits; Stellar Spectral Classification, Hertzsprung-Russell Diagram. **(10 hours)**

Unit 2: Astronomical techniques: Basic Optical Definitions for Astronomy (Magnification Light Gathering Power, Resolving Power and Diffraction Limit, Atmospheric Windows), Optical Telescopes (Types of Reflecting Telescopes, Telescope Mountings, Space Telescopes, Detectors and Their Use with Telescopes (Types of Detectors, detection Limits with Telescopes). **(10 hours)**

Unit 3: Physical principles: Gravitation in Astrophysics (Virial Theorem, Newton versus Einstein), Systems in Thermodynamic Equilibrium, Theory of Radiative Transfer (Radiation Field, Radiative Transfer Equation), Optical Depth; Solution of Radiative Transfer Equation, Local Thermodynamic Equilibrium **(5 hours)**

Unit 4: The sun: The solar family (Solar System: Facts and Figures, Origin of the Solar System: The Nebular Model, Tidal Forces, and Planetary Rings, Extrasolar Planets. Stellar spectra and classification Structure. Atomic Spectra Revisited, Stellar Spectra, Spectral Types, and Their Temperature Dependence, Black Body Approximation, H R Diagram, Luminosity Classification. **(5 hours)**

Unit 5: Stellar structure: Hydrostatic Equilibrium of a Star, Some Insight into a Star: Virial Theorem, Sources of Stellar Energy, Modes of Energy Transport, Simple Stellar Model, Polytropic Stellar Model. Star formation: Basic composition of Interstellar medium, Interstellar Gas, Interstellar Dust, Formation of Protostar, Jeans criterion, Fragmentation of collapsing clouds, From protostar to Pre-Main Sequence **(5 hours)**

Unit 6: Nucleosynthesis and stellar evolution: Cosmic Abundances, Stellar Nucleosynthesis, Evolution of Stars (Evolution on the Main Sequence, Evolution beyond the Main Sequence), Supernovae. Compact stars: Basic Familiarity with Compact Stars, Equation of State and Degenerate Gas of Fermions, Theory of White Dwarf, Chandrasekhar Limit, Neutron Star Black Hole. The milky way:

Basic Structure and Properties of the Milky Way, Nature of Rotation of the Milky Way (Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms), Stars and Star Clusters of the Milky Way, Properties of and around the Galactic Nucleus

(10 hours)

Unit 7: Galaxies: Galaxy Morphology, Hubble's Classification of Galaxies, Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleurs Law, Stars and Gas). Spiral andLenticular Galaxies (Bulges, Disks, Galactic Halo) The Milky Way Galaxy, Gas and Dust in the Galaxy, Spiral Arms, Active Galaxies

(5 hours)

Unit 8: Active galaxies: 'Activities' of Active Galaxies, How 'Active' are the Active Galaxies? Classification of the Active Galaxies, Some Emission Mechanisms Related to the Studyof Active Galaxies, Behaviour of Active Galaxies, The Nature of the Central Engine, Unified Model of the Various Active Galaxies

(4 hours)

Unit 9: Large scale structure & expanding universe: Cosmic Distance Ladder (An Example from Terrestrial Physics, Distance Measurement using Cepheid Variables), Hubble's Law (Distance- Velocity Relation), Clusters of Galaxies (Virial theorem and Dark Matter), Friedmann Equation and its Solutions, Thermal history of the Universe. **(6 hours)**

Prescribed Text Book:

- The physical universe: An introduction to astronomy, F.Shu, Mill Valley: University Science Books.
- Theoretical Astrophysics Volume I : Astrophysical Processes Padmanabhan, T. Published by Cambridge University Press..
- Theoretical Astrophysics Volume II : Star and Stellar Systems Padmanabhan, T. Published by Cambridge University Press..
- Theoretical Astrophysics Volume III : Galaxies and Cosmology Padmanabhan, T. Published by Cambridge University Press..
- Introduction to cosmology, by Jayant V. Narlikar Published by Cambridge University Press..
- Structure formation of the Universe, by T. Padmanabhan Published by Cambridge University Press.

Suggested Additional Readings:

- Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
- Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.
- Fundamental of Astronomy (Fourth Edition), H. Karttunen et al. Springer
- K.S. Krishnasamy, 'Astro Physics a modern perspective,' Reprint, New Age International (p) Ltd, New Delhi,2002.
- Baidyanath Basu, 'An introduction to Astrophysics', Second printing, Prentice - Hall of India Private Limited, New Delhi, 2001.
- Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.

Course Articulation Matrix of PAS7102- Astronomy and Astrophysics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	3	2	3	3	3	1
CO2	3	1	2	3	3	2	2	1
CO3	3	1	3	2	2	3	2	1
CO4	3	1	2	3	3	3	3	1
CO5	3	1	2	3	3	3	3	1

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Solid State Physics and Electronics

Course Code: PAS7201 **Course Type: Major**
Credit: 4
Course Objectives: This course is designed to teach students the basic introduction to solid state physics and its applications in electronic devices. Understanding the basics of crystalline materials will be useful for other high level courses such as condensed matter physics, material characterization and engineering.

Course Outcomes: After the completion of the course, students will:
CO1: Have a basic knowledge of crystal systems and spatial symmetries; Be able to account for how crystalline materials are studied using diffraction, including concepts like the Edwald's sphere, form factor, structure factor, and scattering amplitude.
CO2: Be able to perform structure determination of simple structures; Understand the

concept of reciprocal space and be able to use it as a tool to know the significance of Brillouin zones; Know what phonons are, and be able to perform estimates of their dispersive and thermal properties

CO3: Be able to calculate thermal and electrical properties in the free-electron model and know Bloch's theorem and energy band and distinction between metals, semiconductors and insulators; Be able to estimate the charge carrier mobility and density; Be able to account for what the Fermi surface is and how it can be measured.

CO4: To understand Lattice heat capacity and to compare Classical theory, Einstein's theory, Debye's theory of specific heat of solids; To apply techniques of X-Ray Diffraction and UV Spectroscopy to study crystals; To distinguish between P-N diode, Zener diode, LED and Photodiode.

CO5: To understand Half wave, full wave and bridge rectifiers and filters: capacitance filter, inductor filter and filter; To demonstrate voltage regulation using Zener diode; To understand basic construction and operation of bipolar transistors (NPN and PNP); To distinguish between transistor circuit configurations (CB, CE, CC), current gains and their interrelationship.

Course contents

Unit 1: Crystal Structure and Crystal Bonding: Lattice Translation Vectors. Lattice with a Basis.Unit Cell.Miller Indices.Reciprocal Lattice.Types of Lattices.Brillouin Zones.Diffraction of X-rays by Crystals.Bragg‟s Law.Laue pattern, Laue equation, Atomic and Geometrical Factor.Potential between a pair of atoms, Lennard-Jones potential, Ionic, Covalent, Vander - Waal‟s. Calculation of cohesive energy for ionic and inert gas system. **(10 hours)**

Unit 2: Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons.Qualitative Description of the Phonon Spectrum in Solids.Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law **(5 hours)**

Unit 3: Free electron theory of metals: Classical picture, Fermi gas, density of states, Fermi energy and fermi velocity, electronic contribution to specific heat of metals. **(3 hours)**

Unit 4: Band Theory of Metals: Kronig Penny model, Brillouin zones, electrons in periodic structure, energy bands, energy gaps, effective mass of electrons and holes, metals, insulators, p and n type Semiconductors effective mass of electron, mobility. **(4 hours)**

Unit 5: Superconductivity: Experimental Results. Critical Temperature.Critical magnetic field.Meissner effect. Type I and type II Superconductors, London‟s Equation and Penetration Depth. Isotope effect.cooper pairs, BCS theory. **(8 hours)**

Unit 6: Junction diodes: pn junctions, V-I characteristics, Zener diode, voltage regulation, tunnel diode, LED and LCD, Solar cell, diode as circuit element, load line concept, Rectifiers: Half Wave, full wave and bridge rectifier, efficiency and ripple factor, filter circuits. **(7 hours)**

Unit 7: Transistors: Characteristics of a transistor in CB, CE and CC mode, idea of equivalent circuits, α andβ of BJT, common emitter amplifier. Field Effect Transistor: working of JFET, voltage ampere curves, biasing JFET, ac operation of

JFET, depletion and enhancement mode, MOSFET, FET amplifier.

(8 hours)

Unit 8: Amplifiers: Small signal amplifiers: General principles of operation, classification, distortion, RC coupled amplifier, gain frequency response, input and output impedance. Multistage amplifiers, transformed coupled amplifiers, Equivalent circuits at low, medium and high frequencies, emitter follower, low frequency common source and common drain amplifier, Noise in electronic circuits. Feedback in amplifiers; negative feedback and stability.

(9 hours)

Unit 9: Oscillators: Braukhausen criteria for oscillations, Tuned collector, Hartley and colpitts oscillators, phase shift oscillators, operational amplifiers, inverting and non-inverting amplifiers, operational amplifier as adder, subtractor, comparator, integrator and differentiator. **(6 hours)**

Prescribed Textbooks:

1. Solid State Physics by Neil W. Ashcroft and N. David Mermin
2. Introduction to Solids by Azaroff
3. Crystallography Applied to Solid State Physics by A. R. Verma and O. N. Srivastava
4. Introduction to Solid State Physics by C. Kittle
5. Principles of Condensed Mater Physics by P. M. Chaikin and C. Lubensky
6. Solid State Physics: A. J. Dekker
7. Electronic Principles, A.P. Malvino, 3rd Edition(1984), Tata Mcgraw Hill Edition, New Delhi.
8. Principle of Electronics, VK Mehta, S Chand and Company

Course Articulation Matrix of PAS7201- Solid State Physics and Electronics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	2	2	2	2	1
CO2	3	1	3	3	3	2	2	1
CO3	3	1	3	2	2	3	2	1
CO4	3	1	2	2	3	3	3	1
CO5	3	1	2	3	3	3	3	1

1: Partially related
2: Moderately related
3: Strongly related

Nuclear and Particle Physics

Course Code: PAS7202 **Course Type: Major**
Credit: 4

Course Objectives: The prime aim of this course is to provide

- The general properties of nucleus, models for the nucleus, various theories of the nuclear decay, basics of nuclear reactions and its types and the interaction of the radiation with matter to understand the construction and working of the nuclear radiation detectors.
- Brief introduction to the world of the fundamental particles.

Course Outcomes: After completing the course satisfactorily, a student will be able:

CO1: To analyze the general properties of the nucleus, various models for it, theories of its decay, the interaction of the nuclear radiations with matter and detector as an application.

CO2: To understand the basic properties of the fundamental particles.

Course Contents

Unit 1: General Properties of Nuclei

Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excites states. **(6 hours)**

Unit 2: Nuclear Models

Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermigas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force. **(6 hours)**

Unit 3: Radioactivity decay

1. Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion. **(6 hours)**

Unit 4: Nuclear Reactions

Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering). **(5 hours)**

Unit 5: Interaction of Nuclear Radiation with matter

Energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation, Gamma ray interaction through matter, photoelectric effect, Compton scattering, l pair production, neutron interaction with matter.

(5 hours)

Unit 6: Detector for Nuclear Radiations

Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter, Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT), Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector. **(6 hours)**

Unit 7: Particle physics:

Particle interactions; basic features, types of particles and its families, Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark, model, color quantum number and gluons.

(6 hours)

Prescribed Text Book:

1. Introductory nuclear Physics, Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
2. An Introduction to Nuclear Physics, W.N. Cottingham and D.A. Greenwood, Cambridge University Press.
3. Elements of Nuclear Physics, Walter E. Meyerhof, McGraw-Hill Book Company.
4. Introduction to High Energy Physics, D.H. Perkins, Cambridge Univ. Press

Suggested Additional Readings:

1. Concepts of nuclear physics, Bernard L.Cohen.(Tata Mcgraw Hill, 1998).
2. Introduction to the physics of nuclei &particles, R.A. Dunlap. (Thomson Asia, 2004).
3. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
4. Radiation detection and measurement, G.F. Knoll (John Wiley & Sons, 2000).

Course Articulation Matrix of PAS7202- Nuclear and Particle Physics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	2	3	3	2	1
CO2	3	1	3	3	3	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Quantum mechanics-I

Course Code: PAS8104 **Course Type: Major**
Credit: 4

Course Objectives: The purpose of the course is to provide:

- A comprehensive introduction and application of quantum mechanics for the entire physics.
- Starts from the fundamentals of basic quantum theory.
- Gives a detailed account of the formalism of quantum mechanics and
- Develop pre-requisites to deal with advanced systems using the quantum theory.

Course Outcome: The student shall be able to:
CO1: Solve quantum mechanical problems in 1, 2 and 3 dimensions.
CO2: Understand the basics of the mathematics behind the quantum theory.
CO3: Develop approximation methods for solving problems in quantum mechanics.

Course Content

Unit 1: Fundamentals of Quantum Physics

Schrödinger'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, orthonormality 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, Perceval's theorem. **(12 hours)**

Unit 2: Mathematical Foundations

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. **(15 hours)**

Unit 3: Quantum dynamics

The Schrödinger picture: Unitary time evolution, Schrödinger's equation, The Heisenberg picture: Heisenberg operators, Heisenberg's equation of motion. Linear Harmonic Oscillator by operator method and it's time evolution. **(8 hours)**

Unit 4: Three dimensional problems

Three dimensional problems in Cartesian and spherical coordinates, square wells and harmonic oscillator. Hydrogen atom, radial equation and it's solution. **(5 hours)**

Unit 5: Angular Momentum

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. **(8 hours)**

Unit6: Time Independent Perturbation Theory

Basic concepts, non-degenerate energy levels.The first and second order corrections to the wave function and energy, degenerate perturbation theory, relativistic correction and spin-orbit Interactions. The Zeeman effect and the Stark effect. **(6 hours)**

Unit 7: The Variation Method and WKB Approximation

The Variation Principle, Variation method for excited states. Ground state of Helium.The WKB method, connection formula, validity of the WKB method, tunnelling through a barrier and alpha decay. **(6 hours)**

Textbooks:

1. David J. Griffiths, Introduction to Quantum Mechanics, Pearson Prentice Hall, Inc.
2. J.J. Sakurai, Modern Quantum Mechanics, Addison-Wesley ISBN 0-201-06710-2.

3. R. Shankar, Principles of Quantum Mechanics, Second edition, Plenum Press, New York.
4. E. Marzbacher, Quantum Mechanics, Wiley Student Edition, 2011.
5. Mathews and Venkateshan, Quantum Mechanics, Tata McGraw-Hill 2010.

Reference books:

1. Ashok Das, Quantum Mechanics, Tata McGraw Hill (2007).
2. Leonard. I. Schiff, Quantum Mechanics, 3 edition, Tata McGraw-Hill 2010.
3. S. Weinberg, Quantum mechanics, Cambridge University press.
4. P.A.M. Dirac, The Principles of Quantum Mechanics, Cambridge University press.
5. A. Messiah, Quantum Mechanics, Dover.

Course Articulation Matrix of PAS8104- Quantum Mechanics-I

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	3	2	3	3	2	1
CO2	3	1	3	3	3	2	2	1
CO3	3	1	3	2	2	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Statistical Mechanics

Course Code: PAS8201 **Course Type: Major**
Credit: 4

Course Objectives: Statistical mechanics plays an important role in understanding the bulk and thermodynamical properties of the materials. This course is designed to provide the student an opportunity to understand

- Connection between Thermodynamics and Statistical Mechanics.
- To develop statistical mechanics techniques within the paradigm of ensemble approach and their application in classical ideal and real systems.
- To extend the statistical approach to incorporate quantum ensembles and distributions and their application in quantum ideal and real gases.
- To acquaint the students with statistical techniques like viral expansion, cluster integrals to understand the behaviour of real gases.
- To understand the statistics of spins or magnetic system using mean field theories and to understand first and second order phase transitions as discontinuities in the thermodynamical functions.

Course Outcomes: After the completion of the course the student will be able

CO1: Explain the postulates of classical and quantum statistical mechanics and their ramifications thereof. They will understand to extract the thermodynamics of the system from the statistical behaviour of the system.

CO2: Model the real systems in terms of micro, canonical and grand ensembles and to apply the principles of ensemble approach to selected problems starting from classical ideal gas.

CO3: Understand the basis of ensemble approach in statistical mechanics to a range of situations e.g. ideal Bose systems and Fermi systems.

CO4: Understand the fundamental differences between classical and quantumstatistics and learn about quantum statistical distribution laws.

CO5: The student will be able to explain the Bose-Einstein condensation in various bosonic systems.

CO6: Appreciate the difference between the thermodynamics of the system based on whether it is in degenerate or non-degenerate limit. The student will be able to find the stability condition of white dwarf stars.

CO7: To model magnetic systems using mean field theories and understand phase transition as discontinuities in various thermodynamical functions.

Course Contents

Unit 1: Classical Statistical Mechanics

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. **(5 hours)**

Unit-2: Ensemble Theory: Microcanonical, Canonical Ensemble

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. **(6 hours)**

Unit-3: Ensemble Theory: Grand Canonical Ensemble

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. **(5 hours)**

Unit-4: Quantum Statistical Mechanics: Statistical Distributions

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

(6 hours)

Unit-5: Quantum Gases

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. **(7 hours)**

Unit-6: Approximate Methods and Ising Model

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. **(7 hours)**

Unit-7: Theory of Phase transition

Landau theory of phase transition, Critical indices, Scale transformation and dimensional analysis. **(4 hours)**

Prescribed Text Books:

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

Reference books:

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

Course Articulation Matrix of PAS8201- Statistical Mechanics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	3	3	1	3	3	1
CO2	3	1	3	2	1	3	2	1
CO3	2	1	3	3	2	2	2	1
CO4	3	1	2	3	3	3	1	1
CO5	2	1	2	3	2	2	2	1
CO6	3	1	2	2	2	3	3	1
CO7	3	1	2	2	1	3	3	1

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Minor Courses

Organic Stereochemistry and Spectroscopy

Course Code: CCS5101 **Course Type: IDC Minor**
Credit: 4

Course Contents

Unit 1: Stereochemistry and Conformational Analysis:

Stereochemistry and stereoisomerism,stereochemical nomenclature & terminology, Chirality, the chiral centre,2-D representations (Fischer projections), Optical activity, Plane-polarized light, the polarimeter, Specific rotation, Specification of configuration: R and S, Sequence rules, Diastereomers, Meso structures, Specification of configuration: More than one chiral center, Generation of a chiral center. Threo- and erythro- isomers, methods of resolution and optical purity. Conformational analysis- Conformation of cycloalkanes, Equatorial and axial bond in cyclohexane,Conformation of cycloalkanes, Equatorial and axial bond in cyclohexane, Stereoisomerism of cyclic compounds: *cis*- and *trans*- isomers. **(X hours)**

Unit 2:UV Spectroscopy**:**General principles, Introduction to absorption and emission spectroscopy. Types of electronic transitions, λmax, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption;

Application of Woodward Rules for calculation of λmax for the following systems: α,β unsaturated aldehydes, ketones, carboxylic acids and esters; Conjugated dienes: alicyclic, homoannular and heteroannular; Extended conjugated systems (aldehydes, ketones and dienes); distinction between *cis* and *trans* isomers. **(X hours)**

Unit 3: IR Spectroscopy: Fundamental and non-fundamental molecular vibrations; IR absorption positions of O, N and S containing functional groups; Effect of H-bonding, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in functional group analysis. **(X hours)**

Unit 4: NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin – Spin coupling and coupling constant; Anisotropic effects in alkene, alkyne, aldehydes and aromatics, Interpretation of NMR spectra of simple compounds. **(X hours)**

Reference books:

1. Organic spectroscopy Principles and Applications, Second Edition, Jag Mohan., Narosa Publishing House.
2. Elementary Organic spectroscopy, Principles and chemical Applications, Y.R. Sharma, S. Chand.
3. Advanced Organic Chemistry, Jagdambasingh, L.D.S Yadav

Atomic, Molecular and Laser Physics

Course Code: PAS7103 **Course Type: Minor**
Credit: 4

Course Objectives: The course is designed to learn the basics of spectroscopic (classical
and quantum picture of interaction of radiation with matter), various aspects of atomic and molecular spectra, and understand about Lasers and their applications to non-linear optics.

Course Outcomes: After completion of the course, a student will be able to understand
CO1: the classical and quantum concepts of the interaction of the radiation with matter for understanding the atomic and molecular spectroscopy
CO2: understand the construction and working of LASER.

Course Contents

Unit 1: Interaction of Radiation with Matter

- Classical electrostatics of Molecules in Electric field
- Quantum theory of molecules in static fields in static electric fields
- Classical description of molecules in time dependent fields.
- Time-dependent perturbation theory of radiation-matter interactions
- Selection rules for one-photon transitions **(5 hours)**

Unit 2: Atomic Spectra

- Hydrogenlike Spectra, Spin—Orbit Coupling
- Variational Principle, Hamiltonian for many electron system and Born-Oppenheimer Approximation
- Hartree Theory for He atom
- Hartree-Fock method for excited state of He atom
- Angular Momentum Coupling in Many-Electron Atoms
- Many-Electron Atoms: Selection Rules and Spectra
- The Zeeman Effect **(5 hours)**

Unit 3: Rotation and Vibrational Spectra in Diatomics

- Diatomic Rotational Energy Levels and Spectroscopy
- Vibrational Spectroscopy in Diatomics
- Vibration—Rotation Spectra in Diatomics
- Centrifugal Distortion
- The Anharmonic Oscillator **(5 hours)**

Unit 4: Electronic Spectra in Diatomics

- LCAO—MO Wave Functions in Diatomics
- Molecular Orbital Theory of Hydrogen molecule
- Electronic Spectra in Diatomics
- Flouroscence Spectroscopy
- NMR and ESR **(5 hours)**

Unit 5: Lasers

- General Features and Properties
- Methods of obtaining Population Inversion
- Ray tracing in optical cavities; ABCD law;
- Stability diagram; ray tracing in stable cavity;
- Rate equations for two, three and four level laser systems;
- Spatial and temporal coherence;
- Longitudinal and transverse modes in laser cavities – concepts;
- Q-Switching and Mode Locking **(8 hours)**

Unit 6: Types of Laser

- Solid-state lasers (Ruby, Nd-YAG)
- Gas Lasers (He-Ne, CO_2)
- Semi-conductor lasers
- Ion Lasers (Argon ion and Krypton ion)
- Dye lasers **(4 hours)**

Unit 7: Laser Spectroscopy

- Raman Spectroscopy

- Photoluminescence process
- Non-linear Optics **(8 hours)**

Prescribed Textbooks:

1. Walter S. Struve, Fundamentals of Molecular Spectroscopy, John Whiley and Sons, 1989.
2. Mark Csele, Fundamentals of light Sources and lasers, John Wiley & Sons, Inc., Publication.
3. Jeanne L. McHale, "Molecular Spectroscopy" First Edition, Pearson, 2009.
4. J. Michael Hollas, "Modern Spectroscopy" Fourth Edition, Wiley, 2013.

Reference books:

1. Michael R Muller, "Fundamentals of Quantum Chemistry: Molecular Spectroscopy and Modern Electronic Structure Computations", 1st Edition, Springer, 2001.
2. Elaine M. McCash, Colin N. Banwell, "Fundamentals of Molecular Spectroscopy", 5th Edition, Mc-Graw Hill Education, 2013.
3. G. Aruldhas, Molecular Structure and Spectroscopy, 2nd Edition, PHI Learning, 2009.
4. J Michael Hollas, Basic Atomic and Molecular Spectroscopy, Royal Society of Chemistry, 2002.
5. Straughan, B. P. and Walker, S.: Spectroscopy: (Vols. 1 - 3), Chapman and Hall (1976).
6. Chang, R.: Basic Principles of Spectroscopy, McGraw Hill (1971).
7. Characterization of Materials, E. N. Kaufmann, Wiley (2003).
8. The Optical Resonances in Carbon Nanotubes Arise from Excitons, SCIENCE 838, 308 (2005).
9. Structure-Assigned Optical Spectra of Single-Walled Carbon Nanotubes, SCIENCE 298, 2361 (2002).
10. Principals of Nano-optics, L. Novotny, CUP (2008).
11. A. K. Ghatak and Thyagarajan, "Optical Electronics", Cambridge University Press, 1989.
12. AmnonYariv, "Quantum Electronics", John Wiley & sons, 1987.
13. Verdeyan, "Laser Electronics", Prentice Hall, 1995.

Course Articulation Matrix of PAS7103- Atomic, Molecular and Laser Physics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	2	3	3	1	3	3	1
CO2	3	2	3	2	1	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Computational Physics

Course Code: PAS7203 **Course Type: Minor**
Credit: 4

Course Outcomes: After the completion of the course, students will be able to understand:

CO1: basic numerical techniques to solve ordinary and partial differential equations appearing in some situations in physics.
CO2: Monte-Carlo techniques and its applications in solving integral equations.
CO3: Pseudo-Random number generation and its application in quantum mechanical problems.
CO4: Spectral decomposition techniques and Fourier transforms.

Course Contents

Unit 1: Ordinary Differential Equations:

1. Euler method, Application to Radioactivity, Air drag and ProjectileMotion
2. Euler-Cromet Method, Application to SHO
3. Predictor-corrector method (Heun's) method, Application to Damped Harmonic Oscillator
4. Second order Runge-Kutta method, Application to Forced Oscillations
5. Study of Planetary motion
6. Higher-order Runge-Kutta method; Application to Coupled Oscillations

(8 hours)

Unit 2: Partial Differential Equations:

1. Finite Difference methods: Elliptic Equations- Laplace equation, solutiontechniques and boundary conditions;

2. Parabolic Equations- Heat Conduction Equation, explicit and implicitmethods
3. Crank-Nicholson Method; Application to Schrodinger equation.
4. Finite Element Method: General approach and applications in Onedimension;
5. Application to problems in Electromagnetics. **(8 hours)**

Unit 3: Random Variables and Random Processes:

1. Random variables, several random variables; Statistical averages,function of a random variable, moments, characteristic function, jointmoments; Transformation of random variables; Sequences of randomvariables; central limit theorem (without proof);
2. Random processes; Stationarity; Mean, correlation and covariancefunctions; autocorrelation function and properties , cross-correlationfunctions; Ergodicity; Power spectral density; Gaussian process and itsproperties; **(4 hours)**

Unit 4: Random Processes and Monte-Carlo Methods:

1. Random number generation-uniform and non-uniform distributions;
2. Monte Carlo Integration- Hit and miss, Sample mean integration,
3. Metropolis Method;
4. Computer "Experiments" - applications of Monte-Carlo methods toproblems in physics;
5. Variational Monte-Carlo tecnique: Application to solving for the ground
6. state of quantum mechanical systems in 1D and 2D **(6 hours)**

Unit 5: Fast Fourier Transforms and Spectral Methods:

1. Discrete Fourier Transform,
2. Fast Fourier Transform,
3. SandeTukey Algorithm
4. Pseudospectral technique to solve the Schroedinger equation **(6 hours)**

<u>Course Articulation Matrix of PAS7203- Computational Physics</u>

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	2	1	3	3	2	3	3	1
CO2	2	1	3	3	2	3	2	1
CO3	2	1	3	3	3	3	3	1
CO4	2	1	3	3	3	3	3	1

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Astronomy and Astrophysics Lab

Course Code: PAS8205L **Course Type: Minor**
Credit: 2

Course Objectives: The prime aim of this course is to provide hands-on experience of the astronomy lab.

Course Outcomes: After completing the course satisfactorily, a student will be able:

CO1: To understand the technique used to analyze the astronomy data
CO2: To analyze the data from the astronomy archive
CO3: To get familiar with the night sky
CO4: To learn to use the astronomical software in the various electromagnetic bands.

Course Contents

1. To become familiar with the astronomical objects visible to naked eye in the night sky using the software Stellarium. Go For The Experiment...
2. To become familiar with the Constellations in the night sky using the software Stellarium.Go For The Experiment…
3. To identify the retrograde motion of Mars with respect to the Background stars.Go For The Experiment…
4. To identify some of the prominent spectral lines in the spectrum of our sun.Go For The Experiment…
5. To get familiar with the spectra of different stars.Go For The Experiment…
6. To extract coordinates of a star assuming a telescope in an equatorial mount. You will also learn the concept of sidereal time.Go For The Experiment…
7. To measure astronomical distances using Cepheid variables.Go For The Experiment…
8. To measure the Proper Motion of Barnard's Star.Go For The Experiment…

9. To identify a Circumpolar Star.Go For The Experiment…
10. To determine the distance and age of the cluster using Colour Magnitude Diagram.Go For The Experiment…
11. To determine Orbital Inclination of the planet Mars.Go For The Experiment…
12. To measure planetary distancesGo For The Experiment…
13. To measure distance to the MoonGo For The Experiment…
14. To determine observer's location by means of the starsGo For The Experiment...

Prescribed Text Book:

1. Manual in lab
2. Virtual Astronomy/Astrophysics Laboratory https://va-iitk.vlabs.ac.in/?page=listexp

Course Articulation Matrix of PAS8205L- Astronomy and Astrophysics Lab

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	1	1	3	2	2	3	2	1
CO2	1	1	3	2	2	3	2	1
CO3	1	1	3	2	3	3	2	1
CO4	1	1	3	2	3	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Courses based on Advanced Knowledge in the Discipline

Classical Mechanics

Course Code: PAS8101 **Course Type: AKD**
Credit: 4

Course Objectives:

- Understanding the concepts of classical mechanics which serves as a springboard for the various branches of modern physics.
- To explain Lagrangian and Hamiltonian formulations as alternative frameworks to explain the dynamics of any physical system.
- To explain Hamilton Jacobi theory and the principle of least action which provide the transition to wave mechanics while Poisson brackets and canonical transformations are invaluable in formulating the basic structure of quantum mechanics.

Course Outcomes: After the completion of the course the student will be able to:

CO1: Understand the concepts of degrees of freedom, constraints and write the Lagrangian and/or Hamiltonian for a given system. He/she will be able to write the equations of motion to extract the dynamics of the system.

CO2: Understand the importance of the symmetry in physics, in general and shall understand the emergence of various conservation laws as a consequence of the basic symmetry principles.

CO3: Understand basics of scattering experiments in central force field.

CO4: Solve differential Hamilton's equations and understand the problem in terms of Hamiltonian flow in phase space.

CO5: Write and understand Poisson brackets and canonical transformations between canonical variables and extending it to more fundamental theories.

CO6: Find the points of stable and unstable equilibrium, normal modes and Eigen spectrum of a dynamical system which will be helpful in modeling the thermal and kinetic properties of solids.

<u>Course Contents</u>

Unit 1: Constrained motion and Lagrangian formulation:

- Newtonian mechanics: brief review and limitations.
- Constraints and their classification with examples, principle of virtual work.
- D'Alembert's principle, degrees of freedom, generalised coordinates.
- Lagrange's equation from D'Alembert's principle.
- Lagrangian for various simple mechanical systems such as simple pendulum, Atwood machine, spherical pendulum.
- Charged particle in an electromagnetic field etc., invariance of Euler-Lagrange equations of motion under generalized coordinate transformations.
- Cyclic or ignorable coordinates integrals of motion.

- Concept of symmetry: homogeneity and isotropy, Lagrange's equations of motion for non-holonomic systems. **(8 hours)**

Unit 2: Rotating frame of reference and Central force problem:
- Inertial forces in rotating frame.
- Coriolis force and its effects.
- Reduction to the equivalent one-body problem.
- Stability of orbits, conditions for closure.
- Virial theorem.
- Kepler problem: inverse square law force.
- Scattering in a conservative central force field. **(8 hours)**

Unit 3: Hamilton's equation of motion, Principle of least action and Hamilton principle:
- Legendre transformations, Hamilton's function and Hamilton's equation of motion.
- Routhian, Configuration and phase space.
- Principle of least action, Hamilton's principle.
- Derivation of E-L equations of motion from Hamilton's principle, Derivation of Hamilton's equations of motion for holonomic systems from Hamilton's principle.
- Invariance of Hamilton's principle under generalized coordinate transformation.
- Lorentz invariance of Hamilton's principle functions for the relativistic motion of a free particle. **(6 hours)**

Unit 4: Canonical transformations:
- Equations of canonical transformation (CT), generating functions.
- Properties and examples of canonical transformations.
- Liouville's theorem, Area conservation property of Hamiltonian flows.
- Poisson brackets (PB), Poisson's theorem.
- Invariance of PB under CT, angular momentum Poisson brackets. **(5 hours)**

Unit 5: Theory of Small Oscillations:
- Coupled coordinates, expansion about static equilibrium.
- Normal modes, Two coupled pendulum.
- Linear triatomic molecule. **(3 hours)**

Unit 6: Hamilton Jacobi theory:
- Hamilton Jacobi (HJ) equation.
- Time dependent HJ equation and Jacobi theorem
- Harmonic oscillator problem as an example of the Hamilton Jacobi method.
- Action angle variables and examples. **(5 hours)**

Unit 7: Rigid body dynamics:
- Degree of freedom of a free rigid body.
- Euler's and Chasle's theorem
- Euler's equation of motion for rigid body
- Motion of a heavy symmetric top rotating about a fixed point in the body under the action of gravity precession and nutation. **(5 hours)**

Prescribed Textbooks:

1. Classical Mechanics, H. Goldstein.
2. Classical Mechanics, N. C. Rana and P. S. Joag, Tata McGraw-Hill.

Reference books:

1. Mechanics, L. D. Landau and E. M. Lifshitz.
2. Classical dynamics of particles and systems, J. Marion and S. Thornton, Brooks-Cole.
3. Analytical Mechanics, Louis N. Hand and Janet D. Finch, Cambridge University Press.
4. Classical mechanics for physics graduate students, Ernesto Corinaldesi, World Scientific publishing.
5. Introduction to classical mechanics: with problems and solutions, David Morin, Cambridge University Press.

Course Articulation Matrix of PAS8101- Classical Mechanics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	1	3	3	2	1
CO2	2	1	2	2	3	2	3	1
CO3	3	1	2	2	2	3	2	1
CO4	3	1	2	2	3	3	2	1
CO5	3	1	2	2	3	3	2	1
CO6	3	1	2	2	3	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Classical Electrodynamics

Course Code: PAS8102 **Course Type: AKD**
Credit: 4

Course Objectives: Maxwell's theory of electromagnetic phenomenon is a basic component of all modern courses of theoretical physics and all students of physics must have a thorough knowledge of its principles and working. The basic ingredient of this theory is the concept of a field and the equations which govern the space and time evolution of these fields. These fields are called electromagnetic fields and the equations are known as the Maxwell equations. Moreover, these fields show a wave behaviour and are termed as electromagnetic waves. Visible light is an example of electromagnetic wave. In this course, we shall learn about the working and applications of the Maxwell equations and how it is consistent with the theory of relativity.

Course Outcomes: After successful completion of this course, students shall be able to:

CO1: Evaluate the electrostatic fields and potential in free space and in a dielectric media.

CO2: Evaluate configuration energy of an electrostatic system.

CO3 Understand the production of magnetic field due to steady current and calculate magnetic fields using BoitSavart and Amperes law.

CO4: Understand the Maxwell's equation of electrodynamics and its applications to propagation of electromagnetic waves.

CO5: Understand the concept of wave guide and basic concept of plasma and confinement

Course Contents

Unit 1: Mathematical preliminaries

- Vector analysis: differentiation and integration.
- Dirac's delta function: representation and use. **(4 hours)**

Unit 2: Electrostatics and Magnetostatics

- Scalar and vector potentials.
- Multiple expansion of
- Scalar potential due to a static charge distribution.
- Vector potential due to a stationary current distribution. **(6 hours)**

Unit 3: Maxwell's theory and conservation laws

- Maxwell's equations; charge, energy and momentum conservation(Poynting's vector and Maxwell's stress tensor)
- Electromagnetic fields and wave solution. **(4 hours)**

Unit 4: Radiation from time-dependent sources of charges and currents

- Inhomogeneous wave equations and their solutions;
- Radiation from localised sources and multipole expansion in the radiation zone.

(6 hours)

Unit 5: Radiation from moving point charges

- Lienard-Wiechert potentials;
- Fields due to a charge moving with uniform velocity;
- Fields due to an accelerated charge;
- Radiation at low velocity; Larmor's formula and its relativistic generalisation;
- Radiation when velocity (relativistic) and acceleration are parallel, Bremsstrahlung;
- Radiation when velocity and acceleration are perpendicular, Synchrotron radiation;
- Cherenkov radiation ;
- Radiation reaction, Problem with Abraham-Lorentz formula
- Limitations of classical theory.

(10 hours)

Unit 6: Relativistic formulation of electrodynamics

- Introduction to special relativity: Postulates of Einstein,
- Geometry of relativity, Lorentz transformations.
- Relativistic mechanics: Proper time, proper velocity, Kinematics and dynamics.
- Four vector notation
- Electromagnetic field tensor, covariance of Maxwell's equations.

(10 hours)

Textbooks:

1. D. J. Griffiths: Introduction to electrodynamics, Prentice Hall.
2. W. Panofsky and M. Phillips: Classical electricity and magnetism, Addison Wesley.

Reference books:

1. J. Marion and M. Heald: Classical electromagnetic radiation, Saunders college publishing.
2. L. Landau and E. Lifshitz: Classical theory of fields, Pergamon Press.
3. J. Jackson: Classical electrodynamics, Wiley international.
4. M. Schwartz: Classical electromagnetic theory, Dover publication

Course Articulation Matrix of PAS8102- Classical Electrodynamics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	1	3	3	2	1
CO2	3	1	2	2	3	2	2	1
CO3	3	1	2	2	3	3	3	1
CO4	3	1	2	2	3	3	3	1
CO5	3	1	2	2	3	3	2	1

1: **Partially related**
2: **Moderately related**
3: **Strongly related**

Mathematical Techniques

Course Code: PAS8103 **Course Type: AKD**
Credit: 4

Course Objectives: The course aims to familiarize students to, Matrices,determinants and linear systems,Vector differential calculus, Complex numbers and functions Complex integration

Course Outcome: This gives details about the Mathematical Techniques offered for Master in Science (M.Sc) course in the department of Physics and Astronomical Sciences. After getting this course the student will be acquainted with the basic principles Mathematical Techniques.

CO1: The students will be able to understand complex analytical techniques and its application in various brances of physics.

CO2: understand the matrix algebra and extensions.

CO3: understand complex integration and finite/infinite series solutions.

Course Contents

Unit1: Matrices and their applications-I

Matrices and their operations, linear transformations, special matrices, orthogonal and Unitary matrices. System of linear equations, augmented matrix, rank of matrix, Gauss elimination and Gauss Jordan methods. Linear dependence of vectors and n-dimensional space, ortho normal basis andGarmSchmidtmethod.
(4hours)

Unit2: Matrices and their applications-II

Matrix eigenvalues, eigenvectors of a matrix,Cayley-Hamilton theorem. Theorems about eigen values and applications. Coordinate transformations and matrices. Linear and similarity transformations.Diagonalization of matrices.
(4hours)

Unit3: Complex numbers and functions

Complex numbers and complex plane, Polar form of complex number, roots, Derivative and analyticity, Cauchy-Riemann equations, Analyticity and Laplace's equations. Complex form of exponential, trigonometric,hyperbolicandlogarithmicfunctions. **(4hours)**

Unit4: Complex integration-I

The line integral in a complex plane, ML in equality, Cauchy's integral theorem Cauchy's integral formula, nth order derivatives of analytical function, Cauchy's inequality Power, Taylor, Maclaurin and Laurent series, Radius of convergence Singularities and zeros, Zeros of an analyticalfunction. **(4hours)**

Unit 5: Complex integration-II

Laurent series and Residue integration method.Calculating residues Residue theorem.Applications of residue theorem to solve integrals in complex plane.
(4hours)

Prescribed Textbooks:

1. Mathematical Methods for Physicists by G.Arfken and H.J.Weber, Elsevier Academic Press
2. Mathematical Physics, H. K. Dass, S Chand.

Course Articulation Matrix of PAS8103- Mathematical Techniques

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	3	2	3	3	2	1
CO2	3	1	3	3	3	2	2	1
CO3	3	1	3	2	2	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Advanced Quantum Mechanics

Course Code: PAS8202 **Course Type: AKD**
Credit: 4

Course Objectives: The purpose of the course is to develop:

- The necessary physics and mathematics background obtained in the earlier courses to understand the real life quantum mechanical problems of bound states and scattering states.
- The understanding of the time dependent perturbation theory, symmetries and scattering theory
- Relativistic version of single particle quantum mechanics.

Course Outcomes: The student will be able to

CO1: Define symmetries in a quantum system and use it to define conserved quantities.
CO2: Use these conserved quantities to associate quantum numbers and transitions probabilities.
CO3: Define scattering quantum amplitudes, and the scattering cross- sections.
CO4: Use relativistic quantum properties to understand modifications of energy levels.
CO5: The philosophy of quantum mechanics.

Course Contents

Unit 1: Symmetries in Quantum Mechanics

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 = 1/2 and j = 1; Rotation matrices; Irreducible spherical tensor operators, Wigner-Eckart theorem; Discrete symmetries — parity and time reversal. **(12 hours)**

Unit2: Identical Particles

Meaning of identity and consequences; Symmetric and antisymmetricwavefunctions; Slater determinant; Symmetric and antisymmetric spin wavefunctions of two identical particles; Collisions of identical particles. **(5 hours)**

Unit 3: Time-dependent Perturbation Theory

Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations — Fermi's Golden rule; Sudden and adiabatic approximations. **(8 hours)**

Unit 4: Scattering Theory

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; Ramsauer-Townsend effect; Relation between sign of phase shift and attractive or repulsive nature of the potential; Scattering by a rigidsphere and square well; Coulomb scattering; Formal theory of scattering — Green's function in scattering theory; Lippman-Schwinger equation; Born approximation. **(10 hours)**

Unit 5: Relativistic Quantum Mechanics

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. **(10 hours)**

Unit 6: The measurement problem and recent developments

The Copenhagen interpretation, Pure states and mixed states, Bell states, Bell's inequality and proof. EPR paradox, Entanglement. **(5 hours)**

Text Books:

1. J.J. Sakurai, Modern Quantum Mechanics, Addison-Wesley.
2. R. Shankar, Principles of quantum mechanics, Plenum Press.
3. D. J Griffiths, Introduction to Quantum Mechanics, Pearson Prentice Hall.
4. B. Bransden and C. Joachain, Quantum mechanics, PHI.
5. D. J Griffiths, Introduction to particle physics, Pearson Prentice Hall.

Reference Books:

1. James D. Bjorken and Sidney D. Drell, Relativistic Quantum Mechanics, McGraw-Hill Company.
2. E. Merzbacher Quantum Mechanics, McGraw Hill.
3. L. D. Landau and L. M. Lifshitz, Quantum Mechanics: Non-Relativistic Theory, Butterworth-Heinemann.

Course Articulation Matrix of PAS8202- Advanced Quantum Mechanics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	3	2	3	3	2	1
CO2	3	1	3	3	3	2	2	1
CO3	3	1	3	2	2	3	2	1
CO4	3	1	3	3	3	2	2	1
CO5	1	1	2	1	2	2	1	1

1: Partially related
2: Moderately related
3: Strongly related

Condensed Matter Physics

Course Code: PAS8203 **Course Type: AKD**
Credit: 4
Course Objectives:
This course is designed to teach students the relation between the structure and properties of exhibited by the crystalline solids. The details of band theory and effect of periodic potential on energy dispersions of electron. Role of lattice dynamics in thermal properties of solids. This course also aim to introduce the students to various types of properties of materials such as dielectrics, magnetic and superconducting properties.

Learning Outcomes
After reading this course, the students will be able to:
CO1: understand how the energy dispersions of the electron are affected when large number of atoms come together to form crystalline materials.
CO2: What is the impact of periodic potential on electronic energy states in a crystal? What causes the magneitism in any material and how one can explain various type of magnetic behaviours exhibited different materials.
CO3: The students will also be able to understand the dielectric and superconducting materials and underlying mechanisms to explain their properties.

Unit 1: Structure of solids (9 hours)
Bravais lattice, primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; point group and space group (information only); Common crystal structures: NaCl and CsCl structure, close-packed structure, Zinc blende and Wurtzite structure, tetrahedral and octahedral interstitial sites, Spinel structure; Intensity of scattered X-ray, Friedel's law, Anomalous scattering; Atomic and geometric structure factors; systematic absences; Reciprocal lattice and Brillouin zone; Ewald construction; Explanation of experimental methods on the basis of Ewald construction; Electron and neutron scattering by crystals (qualitative discussion); Surface crystallography; Graphene; Real space analysis — HRTEM, STM, FIM. Non crystalline solids-Monatomic amorphous materials; Radial distribution function; Structureof vitreous silica.

Unit 2: Band theory of solids (6 hours)
Bloch equation; Empty lattice band; Number of states in a band; Effective mass of an electron in a band: concept of holes; Classification of metal, semiconductor and insulator; Electronic band structures in solids - Nearly free electron bands; Tight binding method - application to a simple cubic lattice; Band structures in copper, GaAs and silicon; Topology of Fermi-surface; Quantization of orbits in a magnetic field, cyclotron resonance — de Haas-van Alphen effect; Boltzmann transport equation - relaxation time approximation, Sommerfeld theory of electrical conductivity.

Unit 3: Lattice dynamics and Specific heat (6 hours)
Classical theory of lattice vibration under harmonic approximation; Dispersion relations of one dimension lattices: monatomic and diatomic cases, Characteristics of different modes, long wavelength limit, Optical properties of ionic crystal in the infrared region; Inelastic scattering of neutron by phonon; Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity; Anharmonic effects in crystals - thermal expansion.

Unit 4: Dielectric properties of solids **(6 hours)**

Electronic, ionic, and orientational polarization; static dielectric constant of gases and solids; Complex dielectric constant and dielectric losses, relaxation time, Debye equations; Cases of distribution of relaxation time, Cole - Cole distribution parameter, Dielectric modulus; Ferroelectricity, displacive phase transition, Landau Theory of Phase Transition.

Unit 5: Magnetic properties of solids **(9 hours)**

Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: classical and quantum theory of paramagnetism; case of rareearth and iron-group ions; quenching of orbital angular momentum; Van-Vleck paramagnetism and Pauli paramagnetism; Ferromagnetism: Curie-Weiss law, temperature dependence of saturated magnetisation, Heisenberg's exchange interaction, Ferromagnetic domains - calculation of wall thickness and energy; Ferrimagnetism and antiferromagnetism.

Unit 6: Magnetic resonances **(4 hours)**

Nuclear magnetic resonances, paramagnetic resonance, Bloch equation, longitudinal and transverse relaxation time; spin echo; motional narrowing in line width; absorption and dispersion; Hyperfine field; Electron-spin resonance.

Unit 7: Imperfections in solids **(6 hours)**

Frenkel and Schottky defects, defects by non stoichiometry; electrical conductivity of ionic crystals; classifications of dislocations; role of dislocations in plastic deformation and crystal growth; Colour centers and photoconductivity; Luminescence and phosphors; Alloys, Hume-Rothery rules; electron compounds; Bragg - Williams theory, order-disorder phenomena, superstructure lines; Extra specific heat in alloys.

Unit 8: Superconductivity **(6 hours)**

Phenomenological description of superconductivity - occurrence of superconductivity, destruction of superconductivity by magnetic field, Meissner effect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect; Outlines of the BCS theory; Giaver tunnelling; Flux quantisation; a.c. and d.c. Josephson effect; Vortex state (qualitative discussions); High Tc superconductors (information only).

Reference Books:

- Solid State Physics by Neil W. Ashcroft and N. David Mermin
- Introduction to Solid State Physics by C. Kittle
- Introduction to Solids by Azaroff
- Crystallography Applied to Solid State Physics by A. R. Verma and O. N. Srivastava
- Principles of Condensed Mater Physics by P. M. Chaikin and C. Lubensky
- Solid State Physics: A. J. Dekker

<u>Course Articulation Matrix of PAS8203- Condensed Matter Physics</u>

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	3	1	3	2	3	3	2	1
CO2	3	1	3	3	3	2	2	1
CO3	3	1	3	2	2	3	2	1

1: Partially related
2: Moderately related
3: Strongly related

Indian Knowledge System

(IKS) Courses

Course Code: PAS5106 **Course Type: IKS**
Credit: 4
Course Objectives:

Bhārata has a very rich and versatile knowledge system and cultural heritage. The Bhāratīya knowledge system was developed during the Vedic period, the Saraswatī-Sindhu Civilization, the Middle ages and practiced till the conditions of modern times. In this course, a special attention is given to the reasons of ideas occurrence in the ancient society, and connection with the concept of material world, and religious, social, and cultural beliefs. On the closer examination religion, culture and science have appeared epistemological very rigidly connected in the Bhāratīya knowledge system. As such, this land has provided invaluable knowledge stuff to the society and the world in all the spheres of life; e.g. aeronautics, science, astronomy, mathematics, life science, medical science, architecture, art, music, dance, literature, and drama.

Over the period, most of the works were either lost or confined to the libraries or personal possessions. However, some of the activities are still in practice of the masses unknowing the scientific and practical values. Given the nature of course and diversity of the learners' fields, the course is designed to provide a broad-spectrum of the Bhāratīya knowledge system. The main objectives of this course are as follows:

- Creating awareness amongst the youths about the true history and rich culture of the country;
- Understanding the scientific value of the tradition and culture of the Bhārata;
- Promoting the youths to do research in the various fields of Bhāratīya knowledge tradition;
- Converting the Bhāratīya wisdom into the applied aspect of the modern scientific paradigm;
- Adding career, professional and business opportunities to the youths.

Course Outcomes:

It is expected that after completing this course the students would be quite aware of the rich and versatile knowledge system and cultural heritage of Bhārata. They will be clear about the following points:

CO1: The knowledge system was developed during the Vedic period, the Saraswatī-Sindhu Civilization, the Middle ages and practiced knowingly or unknowingly till date;

CO2: In Bhārata, a special attention was given to the reasons of ideas occurrence, and connection with the concept of material world, and religious, social, and cultural beliefs;

CO3: Bhārata was quite advanced in arts, literature, music, dance, drama, and all other spheres of life including aeronautics, science, astronomy, mathematics, life science, medical science, and architecture.

CO4: Awareness amongst the youths about the true history and rich culture of the country;

CO5: The youth will be an individual with a great sense of patriotism and nation-pride.

CO6: The youths will be self-motivated to do research in the various fields of Bhāratīya knowledge tradition;

CO7: The students would be able to convert Bhāratīya wisdom into the applied aspect of the modern scientific paradigm;

CO8: They will be competent enough to choose the IKS as career at the professional and business levels.

It is also expected that after completion of this course the students will have a holistic insight into the understanding of matter and life.

Course Contents

Unit 1: Bhāratīya Civilization and Development of Bhartiya Knowledge System

Genesis of the land, Antiquity of civilization, On the Trail of the Lost River,Discovery of the Saraswatī River, the Saraswatī-Sindhu Civilization, Traditional Knowledge System, The Vedas, Main Schools of Philosophy (6+3), Ancient Education System, the Takṣaśilā University, the Nālandā University, Alumni, Knowledge Export from Bhārata.

(8 hours)

Unit 2: Arts, Literature, and Scholars in Ancient Bharat

Art, Music, and Dance, Naṭarāja– A Masterpiece of Bhāratīya Art, Literature, Life and works of Agastya, Lopāmudrā, Ghoṣā, Vālmīki, Patañjali, Vedavyāsa, Yājňavalkya, Gārgī, Maitreyī, Bodhāyana, Caraka, Suśruta, Jīvaka, Nāgārjuna, Kaṇāda, Patañjali, Kauṭīlya, Pāṇini, Thiruvalluvar, Āryabhaṭa, Varāhamihira, ĀdiŚaṅkarācārya, Bhāskarācārya, Mādhavācārya.

(8 hours)

Unit 3: Ancient Bhartiya Contribution towards Science & Mathematics

Concept of Matter, Life and Universe, Gravity, Sage Agastya's Model of Battery, Velocity of Light, Vimāna: Aeronautics, Vedic Cosmology and Modern Concepts, BhāratīyaKāla-gaṇanā, Kerala School for Mathematics and Astronomy, History and Culture of Astronomy, Sun, Earth, Moon, and Eclipses, Earth is Spherical and Rotation of Earth, Archaeostronomy; Concepts of Zero and Pi, Number System, Pythagoras Theorem, and Vedic Mathematics.

(8 hours)

Unit 4: Ancient Bhartiya Engineering, Technology & Architecture

Pre-Harappan and Sindhu Valley Civilization, Laboratory and Apparatus, Juices, Dyes, Paints and Cements, Glass and Pottery, Metallurgy, Engineering Science and Technology in the Vedic Age and Post-Vedic Records, Iron Pillar of Delhi, Rakhigarhi, Mehrgarh, Sindhu Valley Civilization, Marine Technology, and Bet–Dwārkā.

(8 hours)

Unit 5: Ancient Bhartiya Contribution in Environment & Health

Ethnic Studies, Life Science in Plants, Anatomy, Physiology, Agriculture, Ecology and Environment, Āyurveda, Integrated Approach to Healthcare, Medicine, Microbiology, Medicine, Surgery, and Yoga, etc.

(8 hours)

Text books:

1. Textbook on The Knowledge System of Bhārata by Bhag Chand Chauhan, Under Publication (2021).
2. History of Science in India Volume-1, Part-I, Part-II, Volume VIII, by Sibaji Raha, et al. National Academy of Sciences, India and The Ram krishan Mission Institute of Culture, Kolkata (2014).

Reference Books:

1. History of Science in India Volume-1, Part-I, Part-II, Volume VIII, by Sibaji Raha, et al. National Academy of Sciences, India and The Ram krishan Mission Institute of Culture, Kolkata (2014).
2. Pride of India- A Glimpse of India's Scientific Heritage edited by Pradeep Kohle et al. Samskrit Bharati (2006).

Course Articulation Matrix of PAS8102- Classical Electrodynamics

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	1	1	2	1	2	2	2	3
CO2	1	1	2	1	1	2	2	3
CO3	1	1	2	1	1	2	2	3
CO4	1	1	2	1	1	2	2	3
CO5	1	1	2	1	1	2	2	3
CO6	1	1	2	1	2	2	2	3
CO7	1	1	2	1	2	2	2	3
CO8	1	1	2	1	2	2	2	3

1: Partially related
2: Moderately related
3: Strongly related

Community Connect Based Course

The ***Unnat Bharat Abhiyan*** scheme from ministry of Human Resource Development is an initiative to connect institutions of higher learning with neighbouring communities. The prime objective of this scheme is to provide a linkage between institutions and communities to employ technologies for upliftment of quality of life of Indian citizens (specifically rural India). Central University of Himachal is dedicated to impart quality education to youth of the country. Alongside this the university is engaged into welfare of nearby community through various community connect programs. In this direction Department of Physics and Astronomical Science has also established a Community Connect Cell (C^3). The C^3 aims to disseminate ideas of physics to contribute for welfare of the nearby community.

Under ***Unnat Bharat Abhiyan***, to actively engage students, one 8 credit ***elective open*** course has been proposed for B.Sc. student to be taken in ***3rd*** Semester. This course shall encourage young minds to explore the creative ideas to contribute for sustainable development of rural India. Under this course the students have to take individual projects or a collaborative group under the supervision of faculty member/s from department. The projects should be around physics discipline such as mentioned below:

1. Awareness on efficient energy usage.
2. Awareness on energy harvesting techniques such as electricity using solar/wind/water energy.
3. Energy storage devices and their usage for common public.
4. Awareness on E-Waste and its management.
5. Innovative projects which ease day to day life of people.
6. Making audio-visual demonstrations for awareness on various areas.
7. Practicing innovative methods of teaching physics concepts to school students.
8. Awareness on technologies such as remote sensing, weather forecast etc. and their usage for common public.

The duration of the project will be for **one semester (3rd Semester)**, during which student have to work on any of the identified problem. The project should be directly concerned with community.

CO1: Develop a sense of societal responsibility of the academia.
CO2: understand the role of academics in contributing towards the upliftment of the underprivileged.
CO3: Problem identification, its semantic analysis and proposing its possible solutions.
CO4: writing analyses report.

Identifying the problem

Students can identify a problem based upon following:

1. Day to day observations of community around their living place.
2. One of the government schemes for welfare of community.
3. Some creative idea/device/model which may be useful for community.

Literature Review

Once the problem is identified, student should do a systematic literature review in first month and should submit the report of the same to the faculty supervisor. Under literature review, student should explore the available view points, options and schemes related to the stated problem. At the end of the literature review various aspects of the choice of the project and plan of execution of the project should be clearly defined.

Scope for implementation

The student should explore possibilities of implementation of available options in reference to the problem identified on the basis of community chosen. The amendments can be suggested for optima impact of the schemes/model.

Coordination with local representatives

The students with the help of community connect cell and faculty supervisor shall arrange for public interactions where he/she can educate people on the project, its importance in their life and benefits that can be extracted from the solutions proposed.

Final report

At the end of the semester, student shall submit a consolidated report of the project to the department. The report can include a short movie of the whole project including statement, importance and benefits of the project.

Financial implications

As the project is associated with community welfare and may involve financial liabilities such as visiting the field areas, preparing some experimental demonstration etc. To avail financial support from department, student has to submit a proposal to the department, which will be screened by a departmental committee. Based upon recommendations of the screening committee full financial assistance may be provided to the student for pursuing the project.

Evaluation

The overall course will be for 400 marks (8 credits) divided as follows.

Midterm exam (100M)

The midterm exam will be for 100 marks. In midterm exam student has to present progress of his work before departmental committee. In presentation the student should clearly state:

- ✓ Objectives of the project
- ✓ Community survey and identification of target community
- ✓ Plan of action with methodology of study
- ✓ Timeline for execution of the project

End term Exam (200M)

The final exam shall be of 200 marks in which student have to submit overall report and presentation before committee of examiners (including external examiner). Out of total 200 marks for end term marks, final report shall be of 100 marks, presentation for 50 marks and assessment of overall impact of the project for 50 marks.

Internal Assessment (100M)

The internal assessment shall be for 100 marks and shall be accessed by concerned supervising faculty. The marks can be split into following categories:

- Attendance (in terms of number of hours spent in community): 25 Marks
- Number of presentations made before supervisor: 25 Marks
- Analysis of outcome: 25 Marks

- Community feedback: 25 Marks

Attendance

Student have to maintain minimum attendance of 75%.

Course Articulation Matrix of Community Connect Project

COs	PO1	PO2	PO3	PO4	PSO1	PSO2	PSO3	PSO4
CO1	1	1	2	1	1	1	2	3
CO2	1	2	3	2	1	1	2	3
CO3	2	2	2	1	1	1	1	3
CO4	2	2	2	2	2	2	2	3
CO5								

1: Partially related
2: Moderately related
3: Strongly related