UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: **Quantum Mechanics and Applications** **Course Code:** **SCUCPH501T**

Semester: **V**

L	T	P	C
4	0	0	4

Objective:

In continuation with modern physics this course is an application of Schrodinger equation to various quantum mechanical problems. This gives fair idea of formulation of eigenvalues and eigen functions.

Unit	Content	Hours
1	**Time dependent Schrodinger equatio**n: Time dependent Schrodinger equation; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigen functions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum. Wave Function of a Free Particle.	10
2	**Time independent Schrodinger equation -** Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wave function as a linear combination of energy eigen functions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wave function; Position-momentum uncertainty principle.	10
3	**Application of Schrödinger Wave Equation -** Particle in one dimensional Box, Square well, Rectangular potential barrier and tunnelling, Linear harmonic oscillator, Spherically symmetric potential, Angular momentum operators and their eigen functions, Concept of spin, Hydrogen atom.	9
4	**Atoms in Electric and Magnetic Fields**: Electron angular momentum. Angular momentum quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Normal Zeeman Effect: Electron Magnetic Moment and Magnetic Energy.	8
5	**Many electron atoms:** Pauli's Exclusion Principle. Symmetric and Antisymmetric Wave Functions. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Spin-orbit coupling in atoms-L-S and J-J couplings.	8

Course Outcomes:

- Understand the historical aspects of development of quantum mechanics.
- Understand and explain the differences between classical and quantum mechanics.
- Students will be able to understand the central concepts and principles in quantum mechanics, such as the Schrodinger equation, the wave function and its statistical interpretation.
- Students will be able to apply Schrodinger equation to various quantum mechanical problems.
- Understand the concepts of angular momentum and spin.

Recommended Text Books

1. A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill.
2. Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed. 2005, Pearson Education.

Recommended Reference Books

1. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
2. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press.

UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: **QUANTUM MECHANICS LAB** **Course Code:** **SCUCPH501P**

Semester: **V**

L	T	P	C
0	0	4	2

Objective:

To utilize computational techniques to study and understand the behavior of quantum systems.

List of Experiments:

Use C/C^{++}/Scilab for solving the following problems based on Quantum Mechanics like

1. Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:

$$\frac{d^2y}{dr^2} = A(r)\,u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E] \text{ where } V(r) = -\frac{e^2}{r}$$

Here, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e = 3.795 (eVÅ)$^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511x10^{6} eV/c^{2}.

2. Solve the s-wave radial Schrodinger equation for an atom:

$$\frac{d^2y}{dr^2} = A(r)\,u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened coulomb potential

$$V(r) = -\frac{e^2}{r}e^{-r/a}$$

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take e = 3.795 (eVÅ)$^{1/2}$, m = 0.511x10^{6} eV/c^{2}, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973 (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

3. Solve the s-wave radial Schrodinger equation for a particle of mass m:

$$\frac{d^2y}{dr^2} = A(r)\,u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

For the anharmonic oscillator potential

$$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c^{2}, k = 100 MeV fm^{-2}, b = 0, 10, 30 MeV fm^{-3}In these units, cħ = 197.3 MeV fm. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.

4. Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule:

$$\frac{d^2y}{dr^2} = A(r)\,u(r), A(r) = \frac{2m}{\hbar^2}[V(r) - E]$$

Where μ is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D\left(e^{-2\alpha r'} - e^{-\alpha r'}\right), r' = \frac{r - r_o}{r}$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

Take: m = 940x10^{6}eV/C^{2}, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å

Reference Books:

1. Schaum's outline of Programming with C++.J. Hubbard, 2000, McGraw-Hill Publication
2. An introduction to computational Physics, T.Pang, 2nd Edn.,2006, Cambridge Univ. Press.
3. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific & Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández.2014 Springer.
4. Scilab (A Free Software to Matlab): H. Ramchandran, A.S. Nair. 2011 S. Chand & Co.
5. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press.

UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: SOLID STATE PHYSICS **Course Code:** SCUCPH502T

Semester: V

L	T	P	C
4	0	0	4

Objective:
This syllabus gives an introduction to the basic phenomena in Solid State Physics. This aims to provide a general introduction to theoretical and experimental topics in solid state physics.

Unit	Content	Hours
1	**Crystal Structure:** Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis– Central and Non-Central Elements. Symmetry Elements Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Laue Condition, Atomic and Geometrical Factor.	12
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.	9
3	**Electrons in Solids:** Electrons in metals- Drude Model, Density of states (1-D,2-D,3-D), Elementary band theory: Kronig Penny model. Band Gap., Effective mass, mobility, Hall Effect (Metal and Semiconductor).	8
4	**Dielectric and Magnetic Properties of Materials:** Electronic, ionic and dipolar polarizability, local fields, induced and oriented polarization-molecular field in dielectric, Clasius - Mosotti relation. Dia, Para and Ferromagnetic Materials. Classical Langevin Theory of dia – and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains, B-H Curve. Hysteresis, soft and hard material and Energy Loss.	11
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. Idea of BCS theory (No derivation)	5

Course Outcomes

- Students should be able to elucidate the main features of crystal lattices and phonons.
- Understand the elementary lattice dynamics and its influence on the properties of materials.
- Describe the main features of the physics of electrons in solids.
- Explain the dielectric and magnetic properties of solids and understand the basic concept in superconductivity.

Recommended Text Books

1. Introduction to Solid State Physics, Charles Kittel, 8th Edn., 2004, Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, J.P. Srivastava, 2nd Edn., 2006, Prentice-Hall of India.

Recommended Reference Books

1. Solid State Physics, Rita John, 2014, McGraw Hill.
2. Solid State Physics, M.A. Wahab, 2011, Narosa Publications.

Syllabus for B.Sc. (Hons.) Physics

Course Title: **SOLID STATE PHYSICS LAB** **Course Code:** **SCUCPH502P**

Semester: **V**

L	T	P	C
0	0	4	2

Objective:

To enhance understanding of solid-state physics through practical experimentation.

List of Experiments:

At least 06 experiments from following:

1. Measurement of susceptibility of paramagnetic solution (Quinck`s Tube Method)
2. To measure the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. To measure the Dielectric Constant of a dielectric Materials with frequency.
5. To determine the refractive index of a dielectric using SPR technique.
6. To study the PE Hysteresis loop of a Ferroelectric Crystal.
7. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
8. To measure the resistivity of a semiconductor (Ge) with temperature (up to 150^{o}C) by four-probe method and to determine its band gap.
9. To determine the Hall coefficient of a semiconductor sample.
10. To measure the resistivity of a semiconductor (Ge) with temperature by two-probe method and to determine its band gap.
11. Analysis of X-Ray diffraction data in terms of unit cell parameters and estimation of particle size.
12. Measurement of change in resistance of a semiconductor with magnetic field.

Reference Books:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. A Text Book of Practical Physics, I.Prakash& Ramakrishna, 11^{th} Ed., 2011, Kitab Mahal
3. Elements of Solid State Physics, J.P. Srivastava, 2^{nd} Ed., 2006, Prentice-Hall of India.

UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: **Analog Systems and Applications** **Course Code:** **SCUCPH503T**

Semester: V

L	T	P	C
4	0	0	4

Objective:

To equip students with a strong foundation in analog electronics, enabling them to understand, design, and work with a wide range of analog circuits and systems in various fields.

Unit	Content	Hours
1	**Bipolar Junction Transistors**: n-p-n and p-n-p transistors, Characteristics of CB, CE and CC Configurations, Active, Cut-off and Saturation Regions.Current gains α and β, Relation between α and β, Load line analysis of Transistors, DC Load line and Q-point, Physical Mechanism of current flow. **Transistors Biasing**: Transistor Biasing and Stabilization circuits, Fixed Bias and Voltage Divider Bias.	9
2	**Amplifiers**: Transistors as 2-port network h-parameter Equivalent Circuit, Analysis of a single stage CE amplifier using Hybrid Model, Input and Output impedance, Current, Voltage and Power Gains, Classification of class A, B and C amplifiers, Push-pull amplifier (classB).	10
3	**Coupled Amplifier**: RC-coupled amplifier and its frequency response. **Feedback in Amplifiers**: Effect of Positive and Negative Feedback on In- put Impedance, Output Impedance, Gain Stability, Distortion and Noise. Sinusoidal **Oscillations**: Barkhausens Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency, Hartley and Colpitts oscillators.	11
4	**Operational Amplifiers** (Black Box approach): Characteristics of an Ideal and Practical OP-AMP (IC741).Open-loop and Closed loop Gain. Frequency Response. CMRR, Slew Rate and concept of virtual ground.	6
5	**Application of Op-Amps**: Inverting and non-inverting amplifiers, Adder, Subtractor, Differentiator, Integrator, Log amplifier, Zero crossing detector, Wein bridge oscillator.	9

Course Outcome:

- To learn about the physics of bipolar junction transistors, transistor biasing and stabilization circuits.
- Understand the concept of amplifiers.
- Study the concept of coupled amplifier, feedback in amplifiers and oscillators.
- Study the concept of operational amplifiers.
- Understand the applications of operational amplifier.

Recommended Text Books

1. Electronic devices and circuits R.L.Boylstad (Pearson India)
2. Electronic Principles- A.P.Malvino (Tata Mc Graw Hill)
3. Principles of Electronics- V. K. Mehta and Rohit Mehta (S. Chand Publication)
4. OP-Amps and Linear Integrated Circuit-R. A. Gayakwad (Prentice Hall)
5. PhysicsofSemiconductordevices,DonaldANeamen(Prentice Hall)

Recommended Reference Books

1. Foundations of Electronics-Raskhit and Chattopadhyay (New age International Publication)
2. Concept of Electronics- D.C. Tayal (Himalay Publication)

Syllabus for B.Sc. (Hons.) Physics

Course Title: **Analog System And Application Lab** **Course Code:** **SCUCPH503P**

Semester: **V**

L	T	P	C
0	0	4	2

Objective:

To familiarize students with different apparatus and their applications in measuring various physical quantities.

List of Experiments:

At least 06 experiments from following:

1. To study the V-I characteristics of a Zener diode and its use as voltage regulator.
2. Study of V-I & power curves of solar cells, and find maximum power point & efficiency.
3. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
4. To study the various biasing configurations of BJT for normal class A operation.
5. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
6. To study the frequency response of voltage gain of a 2-stage RC-coupled transistor amplifier.
7. To design a Wien bridge oscillator for given frequency using an op-amp.
8. To design a phase shift oscillator of given specifications using BJT.
9. To design a digital to analog converter (DAC) of given specifications.
10. To design an inverting amplifier using Op-amp (741,351) for dc voltage of given gain.
11. To investigate the use of an op-amp as an Integrator.
12. To investigate the use of an op-amp as a Differentiator.

Reference Books:

1.Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller, 1994, Mc Graw Hill.
2. Modern Digital Electronics, R.P. Jain, 4th Edition, 2010, Tata McGraw Hill.
3. Basic Electronics: A text lab manual, P.B. Zbar, A. P. Malvino, M.A. Miller, 1994, Mc-Graw Hill.
4. Microprocessor Architecture Programming and appl. with 8085, R.S. Goankar, 2002, Prentice Hall.
5. Microprocessor 8085:Architecture, Programming and interfacing, A. Wadhwa, 2010, PHI Learning

UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: **AI AND MACHINE LEARNING** **Course Code:** **CASCPSC50T**

Semester: **V**

L	T	P	C
4	0	0	4

Objective:

To understand the basics of the theory and practice of Artificial Intelligence as a discipline and machine learning algorithms along with their strengths and weaknesses.

Unit	Content	Hours
1	**Introduction to Artificial Intelligence:** Definition, Future of Artificial Intelligence, Characteristics of Intelligent Agents, Typical Intelligent Agents – Problem Solving Approach to Typical AI problems.	9
2	**Introduction to the basic concepts of Probability:** Conditional Probability, Bayes theorem and naive bayes, Random Vectors, Expectation, Correlation, Covariance.	9
3	**Knowledge Representation:** First Order Predicate Logic, Prolog Programming, Unification: Forward Chaining-Backward, Chaining, Resolution, Knowledge Representation, Ontological Engineering-Categories and Objects, Events, Mental Events and Mental Objects, Reasoning Systems for Categories, Reasoning with Default Information.	9
4	**Introduction to Machine Learning:** Fundamentals of ML, supervised, unsupervised, reinforcement learning; **Supervised Learning:** **Classification**: kNN, Centroid Method, Perceptron, Support Vector Machines, Multi-level Perceptron, Decision tree **Regression:** Linear Regression	9
5	**Neural Network:** Introduction to neural networks, Fundamental concepts- neuron models and basic learning rules; Single layer neural Networks, input layer, output layer, hidden layers, Multilayer Neural Networks, Backpropagation.	9

Course Outcome

- Understand the basics of the theory and practice of Artificial Intelligence as a discipline and about intelligent agents.
- The student will learn to apply knowledge representation techniques and problem solving strategies to common AI applications.
- Student should be aware of techniques used for classification and clustering.
- To apply the algorithms to a real-world problem, optimize the models learned and report on the expected accuracy that can be achieved by applying the models.

Recommended Text Books

1. S. Russell and P. Norvig, "Artificial Intelligence: A Modern Approach‖, Prentice Hall, Third Edition, 2009.
2. I. Bratko, ―Prolog: Programming for Artificial Intelligence‖, Fourth edition, Addison-Wesley Educational Publishers Inc., 2011.
3. Biostatistics -A Foundation for Analysis in the Health Sciences' by Wayne E. Daniel and Chad L. Gross.
4. Fundamental of Biostatistics, by Bernard Rosner.
5. Kevin Murphy , Machine Learning: a Probabilistic Perspective, 2012.

Syllabus for B.Sc. (Hons.) Physics

Course Title: **AI AND MACHINE LEARNING LAB** **Course Code:** **CASCPSC50P**

Semester: **V**

L	T	P	C
0	0	4	2

Objective:

To familiarize students with machine learning algorithms to solve problems of moderate complexity.

List of Experiments:

At least 06 experiments from following:

1. Write a python program to remove punctuations from the given string.
2. Write a program to implement Tic-Tac-Toe game using python.
3. Implement the rule base classifier.
4. Implement the Regression algorithm in order to fit data points. Select appropriate data set for your experiment and draw graphs.
5. Write a program to implement k-Nearest Neighbour algorithm to classify the iris data set.
6. Implement the Decision Tree Representation for Appropriate Problems.
7. Write a program to demonstrate the working of the decision tree for a given data set.
8. Handling Training Examples with missing values.
9. Implement to Cluster the data using K-Means algorithm
10. To develop ANN classification model.

Reference Books:

1. S. Russell and P. Norvig, "Artificial Intelligence: A Modern Approach‖, Prentice Hall, Third Edition, 2009.
2. I. Bratko, ―Prolog: Programming for Artificial Intelligence‖, Fourth edition, Addison-Wesley Educational Publishers Inc., 2011.

UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: **Electromagnetic Theory** **Course Code:** **SCUCPH601T**

Semester: **VI**

L	T	P	C
4	0	0	4

Objective:
To introduce the concepts of Maxwell's equations, propagation of electromagnetic (em) waves and their applications in practical problems, production and detection of different types of polarized em waves and general information as waveguides.

Unit	Content	Hours
1	**Maxwell Equations:** Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density. Momentum Density and Angular Momentum Density.	10
2	**EM Wave Propagation in Unbounded Media:** Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth.	6
3	**EM Wave in Bounded Media:** Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection.	8
4	**Polarization of Electromagnetic Waves:** Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light. Rotatory Polarization: Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade polarimeter.	14
5	**Wave Guides:** Propagation of e.m. wave through transmission line, reflection coefficient, standing wave, characteristic impedance, propagation constant. Rectangular waveguides. Expressions for field components, TE, TM & TEM modes. Propagation properties, cutoff frequency, group & phase velocity.	7

Course Outcome

- Understand the basic concepts related to electromagnetic fields.
- Understand the concepts related to electromagnetic wave propagation.
- Production and detection of detection of different types of polarized em waves.
- Apply Maxwell's equations to solutions of problems relating to transmission lines and waveguides.

Recommended Text Books

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
3. Optics, A. Ghatak, 5th Edn., 2012, Tata McGraw Hill Education.

Recommended Reference Books

1. Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning.

2. Classical Electrodynamics, J.D. Jackson, 3rd Edn., 2010, Wiley

Syllabus for B.Sc. (Hons.) Physics

Course Title: ELECTROMAGNETIC THEORY LAB **Course Code: SCUCPH601P**

Semester: VI

L	T	P	C
0	0	4	2

Objective:

The laboratory content compliments the theoretical knowledge of Electromagnetic Theory and gives hands-on experience. Also, it provides the observational understanding of the subject. It enhances the qualitative and quantitative skills of the students.

List of Experiments:

At least 06 experiments from following:

1. To verify the law of Malus for plane polarized light.
2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyze elliptically polarized Light by using a Babinet's compensator.
4. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
5. To study the reflection, refraction of microwaves.
6. To study Polarization and double slit interference in microwaves.
7. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
8. To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
9. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.
10. To determine Boltzmann constant using V-I characteristics of PN junction diode.
11. To find Numerical Aperture of an Optical Fibre.
12. To verify Brewster's Law and to find the Brewster's angle.

Reference Books:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
3. Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer.

UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: **STATISTICAL MECHANICS** **Course Code:** **SCUCPH602T**

Semester: **VI**

L	T	P	C
4	0	0	4

Objective:
The main objective of this course work is to introduce the techniques of Statistical Mechanics which has applications in various fields including Astrophysics, Semiconductors, Plasma Physics, Bio-Physics, Chemistry and in many other directions.

Unit	Content	Hours
1	**Classical Statistics:** Macrostate and Microstate, Phase Space, Elementary Concept of Ensemble, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur-Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations, Thermodynamic Functions of a Two- Energy Levels System, Negative Temperature.	16
2	**Systems of Identical particles:** Collection of non-interacting identical particles. Classical approach and quantum approach: distinguishability and indistinguishability. Occupation number and MB distribution, emergence of Boltzmann factor. Composite system postulate and symmetry postulate of quantum mechanics (for a pair of particles only). Bosons and Fermions. Symmetric and Antisymmetric wave functions. state counting for bosons and fermions.	6
3	**Bose-Einstein Statistics:** B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description).	8
4	**Fermi-Dirac Statistics:** Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals due to electrons.	8
5	**Theory of Radiation:** Properties of Thermal Radiation. Blackbody Radiation. Pure temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Wien's Displacement law. Wien's Distribution Law. Rayleigh-Jean's Law. Ultraviolet Catastrophe. 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.	7

Course Outcome:

- Apply the principles of statistical mechanics to selected problems and to a range of situations.
- Understand the statistics of particles and can easily distribute bosons, fermions and classical particles among energy levels.
- Students will be able to employ fundamental physics concepts and theories to set up and formulate problems in thermodynamics and statistical mechanics.
- After studying Fermi-Dirac statistics, student will be able deal with many electron system in real life.

Recommended Text Books

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
2. Introductory Statistical Mechanics, R. Bowley and M. Sanchez, 2nd Edn., 2007, Oxford Univ. Press.
3. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill

Recommended Reference Books

1. An Introduction to Statistical Mechanics & Thermodynamics, R. H. Swendsen, 2012, Oxford Univ. Press.
2. Statistical Physics , F. Mandl, 2nd Edn., 2003, Wiley.

UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: **STATISTICAL MECHANICS LAB** **Course Code:** **SCUCPH602P**

Semester: VI

L	T	P	C
0	0	4	2

Objective:
To deepen students understanding of Statistical Mechanics.

List of Experiments:

Use C/C^{++}/Scilab/other numerical simulations for solving the problems based on Statistical Mechanics like

1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the Lennard-Jones potential, varying the total number of particles N and the initial conditions:
   a) Study of local number density in the equilibrium state (i) average; (ii) fluctuations
   b) Study of transient behavior of the system(approach to equilibrium)
   c) Relationship of large N and the arrow of time
   d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution
   e) Computation and study of mean molecular speed and its dependence on particle mass
   f) Computation of fraction of molecules in an ideal gas having speed near the most probable speed
2. Computation of the partition function Z(β) for examples of systems with a finite number of single particle levels (e.g., 2 level, 3 level, etc.) and a finite number of non-interacting particles N under Maxwell-Boltzmann, Fermi-Dirac and Bose- Einstein statistics:
   a) Study of how Z(β), average energy <E>, energy fluctuation ΔE, C_V, depend upon the temperature, total number of particles N and the spectrum of single particle states. b) Ratios of occupation numbers of various states for the systems considered above
   c) Computation of physical quantities at large and small temperature T and comparison of various statistics at large and small temperature T.
3. Plot Planck's law for Black Body radiation and compare it with Raleigh-Jeans Law at large and small wavelength for a given temperature.
4. Plot Specific Heat of Solids (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debye distribution function for high temperature and low temperature and compare them for these two cases.
5. Plot the following functions with energy at different temperatures
   a) Maxwell-Boltzmann distribution
   b) Fermi-Dirac distribution
   c) Bose-Einstein distribution
6. Plot the distribution of particles w.r.t. energy (dN/dε versus ε) for
   a) Relativistic and non-relativistic bosons both at high and low temperature.
   b) Relativistic and non-relativistic fermions both at high and low temperature.

Reference Books:

1. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn. 2007, Wiley India Edition.
2. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.
3. Introduction to Modern Statistical Mechanics, D.Chandler, Oxford University Press, 1987.
4. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.
6. Statistical and Thermal Physics with computer applications, Harvey Gould and Jan Tobochnik, Princeton University Press, 2010.

UNITED UNIVERSITY PRAYAGRAJ

Syllabus for B.Sc. (Hons.) Physics

Course Title: **CLASSICAL MECHANICS** **Course Code:** **SCUCPH603T**

Semester: **VI**

L	T	P	C
4	0	0	4

Objective:
This syllabus aims to introduce students to the Lagrangian and Hamiltonian formulations of Newtonian mechanics for providing a deeper understanding of the fundamental principles of physics.

Unit	Content	Hours
1	**Lagrangian :** Generalised coordinates and velocities, Constraints, principle of virtual work Calculus of variation, Lagrange's equation, Applications to simple systems such as coupled oscillators. Cyclic coordinates, symmetries and conservation laws. Advantages of Lagrangian: electromechanical Analogies.	13
2	**Hamiltonian**: Canonical momenta & Hamiltonian. Hamilton's equations of motion. Principle of least action. Applications: Hamiltonian for a harmonic oscillator, compound pendulum. Canonical transformation, Poisson Brackets, Hamilton-Jacobi theory, solution of harmonic oscillator using Hamilton-Jacobi theory.	12
3	**Motion under central force: T**wo body problem, reduction to the equivalent one body problem, Differential equation for the orbit, Condition for stable circular orbit , Kepler's law, centre of mass and lab frame of reference, Rutherford scattering.	8
4	**Rigid body dynamics:** moment of inertia and product of inertia, rotating top, precession and nutation, Euler angles	7
5	**Rotating frame of reference:** rotating frame of reference, centrifugal force, Coriolis force and its effects.	5

Course Outcomes

- Students acquire basic knowledge of Mechanics, skills and techniques to solve a mechanical problem.
- Students will gain the ability to identify appropriate generalized coordinates for a given mechanical system.
- Students will be able to identify the motion of a mechanical system using Lagrange-Hamiltonian formalism.
- Students will learn how to formulate and solve Hamilton's equations.
- Provides deeper understanding of classical mechanics beyond Newtonian mechanics.

Recommended Text Books

1. Intoduction to Classical mechanics, Nikhil Ranjan Roy, 2016, Vikash Pub House Pvt. Ltd.
2. Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rd Edn. 2002,Pearson Education.

Recommended Reference Books

1. Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
2. Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.

Syllabus for B.Sc. (Hons.) Physics

Course Title: **CLASSICAL MECHANICS LAB** **Course Code:** **SCUCPH603P**

Semester: **VI**

L	T	P	C
0	0	4	2

Objective:

To provide a hands – on and experimental approach to understanding and applying the principles of classical mechanics.

List of Experiments:

At least 06 experiments from following:

1. To determine the acceleration due to gravity by object drop method.
2. To determine the acceleration due to gravity by Simple Pendulum.
3. To determine the acceleration due to gravity with the help of Compound Pendulum.
4. To determine the radius of gyration and moment of inertia of a Compound Pendulum about its centre of gravity.
5. Determination of the moment of inertia of given body using inertia table.
6. Determination of the moment of inertia of given body using inertia table using lamp and scale arrangement.
7. Prove the perpendicular axis theorem of moment of inertia using inertia table.
8. Study two normal modes of Coupled Oscillator and record the oscillations to determine the time period for both the modes.
9. Record the oscillations for Resonance Mode. To determine the Coupled Time Period and Beat Time Period of the oscillation also compare the experimental values of time period with calculated values?
10. To determine the Spring Constant with the help of Coupled Oscillator.

Reference Books:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. A Text Book of Practical Physics, I.Prakash& Ramakrishna, 11th Ed., 2011, Kitab Mahal.

Syllabus for B.Sc. (Hons.) Physics

Course Title: **NANO MATERIALS AND APPLICATIONS** **Course Code:** **SCUCPH604T**

Semester: **VI**

L	T	P	C
2	0	0	2

Objective: The objective of this course is to introduce the essence of nano materials and their applications.

Unit	Content	Hours
1	**Nanoscale Systems:** Band structure and density of states of materials at nanoscale, size effects in nano systems, Quantum confinement Applications of Schrodinger equation-infinite potential well, potential step, potential box, quantum confinement of carriers in 3D, 2D, 1D nanostructure and its consequences.	8
2	**Synthesis of Nano structure Materials:** Top down and botton up approach, Photo lithography Ballmilling. Gas phase condensation, Vacuum deposition, Physical vapour deposition (PVT): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition, Chemical vapour deposition (CVD), Sol-Gel Electro deposition, Spray pyrolysis.	8
3	**Characterization**: X-Ray Diffraction, Optical Microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunneling Microscopy.	8
4	**Applications**: Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron devices (no derivation). CNT based transistors. Nanomaterial Devices:	6

Course Outcome:

- To correlate properties of nanostructures with their size, shape and surface characteristics.
- Student will able to understandthe appropriate synthesis technique to synthesize quantum nanostructures of desired size, shape and surface properties.
- Students will learn different methods of nano material charecterization. .
- To provide scientific understanding of application of nanomaterials

Recommended Text Books

1. S.K. Kulkarni, Nanotechnology: Principles and Practices (Capital publishing Company)
2. Nano science and nano technology, K.K.Choudhury (Narosa)

Recommended Reference Books

1. Nano Science and nanotechnology, SundarSingh (PragatiPrakashan)
2. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology (Wiley India Pvt.Ltd.)
3. Introduction to Nanoelectronics, VV. Mitin, VA. Kochelap & M.A. Stroscio, 2011, Cambridge University Press.
4. Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons).