Exam Code: 225502 **Paper Code: 2214**

Programme: Master of Science (Physics) Semester: II

Course Title: Quantum Mechanics-I

Course Code: MPHL-2391

Time Allowed: 3Hours **Max Marks: 70**

Note: Attempt five questions in all, selecting atleast one question from each section. Fifth question may be attempted from any section. Each question carries 14 marks.

Section-A

1. Derive the canonical commutation any two components of momentum, any two components of position and between any two components of position and momentum operators. Discuss their significance in quantum mechanics. **14**

2. a. Two observables A and B have the commutation relation: $[A, B] = i\hbar$. Show that A and B cannot have simultaneous eigenkets. **3.5**
   b. State and prove Schwarz Inequality. **3.5**
   c. Using the rules of bra-ket algebra, prove that tr(XY) = tr(YX), where X and Y are operators. **3.5**
   d. Suppose $|i\rangle$ and $|j\rangle$ are eigenkets of some Hermitian operator A. Under what condition can we conclude that $|i\rangle + |j\rangle$ is also an eigenket of A? Justify your answer. **3.5**

Section-B

3. State Ehrenfest's theorem and discuss its implications for quantum mechanical systems. Provide a mathematical derivation of the theorem and illustrate its application with an example. **14**

4. a. Define the time evolution operator and explain its significance in quantum mechanics. Derive the time-dependent Schrödinger equation for the time evolution operator. **4.5**

   b. Compare the Schrödinger picture and the Heisenberg picture in quantum mechanics. Discuss the role of Heisenberg picture in the derivation of equation of motion of a quantum particle. Derive the equation of motion of quantum particle. **5**

   c. Discuss the special role of the Hamiltonian operator in quantum mechanics. **4.5**

Section-C

5. a. Discuss the principle of time reversal invariance in quantum mechanics. **3**

   b. Define the parity as a discrete quantum symmetry. Explain the behaviour of wave function under parity. Prove that Hamiltonian remains conserved under parity. **11**

6. a. What are continuous symmetries in quantum mechanics? Prove that symmetries deals to the conservation laws. **9**

   b. Discuss the concepts of space-translation and rotation symmetry in quantum mechanics. **5**

Section-D

7. Solve the quantum mechanical system to obtain the energy eigen values and energy eigen states of an isotropic three dimensional simple harmonic oscillator. **14**

8. Find the CG coefficients for a system having $j_1=3/2$ and $j_2=1/2$. **14**

Exam Code: 225502 **Paper Code: 2215**

Programme: Master of Science (Physics) Semester: II

Course Title: Electrodynamics-I

Course Code: MPHL-2392

Time Allowed: 3Hours **Max Marks: 70**

Note: Attempt five questions in all, selecting atleast one question from each section. Fifth question may be attempted from any section. Each question carries 14 marks.

Section-A

1 a) Volume charge is distributed throughout the space in such a way that the electrostatic potential at a point at a distance r from the origin is $\varphi = \frac{1}{\sqrt{c^2+r^2}}$ where c is a constant. Show that the charge density is given by $\rho = \frac{3c^2}{4\pi\sqrt[5]{c^2+r^2}}$. (5)

1 b) Derive a relation between molecular polarizability and electric susceptibility when a material of polarizable molecules is put in external electric field. (5)

1 c) Discuss the concept of method of images. Give illustration. (4)

2a) State Gauss law. Express Gauss law in integral and differential form. (5)

2b) Find the charge density and the total charge of the system which gives rise to the electric field E(x) = $\frac{qe^{-\alpha r}}{r^3}\boldsymbol{x}$ (5)

2c) State and prove uniqueness theorem. (4)

Section-B

3a) Starting from the Biot Savart's law, obtain the curl and divergence of magnetic field **B** . (5)

3 b) Obtain the expression for multipole expansion(first three terms) of the vector potential of an arbitrary current distribution. (5)

3 c) If at any position vector potential $\mathbf{A} = 10(x^2 + y^2 + z^2)\hat{\imath}$. Evaluate the magnetic field at that position. (4)

4 a) Calculate the torque on a dipole in a uniform magnetic field. (4)

4 b) Using electron theory of magnetism show that a diamagnetic substance is feebly repelled by a magnet and show that diamagnetic susceptibility is independent of temperature. (5)

4 c) Obtain the differential form of Ampere's law. (5)

Section-C

5 a) Explain any two Maxwell equations regarding faraday law and ampere law in detail and give their significance. (7)

5 b) Derive the poynting theorem for complex field vectors. (7)

6 a) Derive law of conservation of linear momentum of an electromagnetic field. (7)

6 b) What do you mean by choosing a gauge? What is gauge transformation? Discuss Coulomb gauge. (7)

Section-D

7a) An em wave with its electric field vector parallel to the plane of incidence strikes a dielectric-dielectric interface. Deduce the reflection and transmission coefficients of energy. (9)

7 b) Explain the concept of Total Internal Reflection. Give its two recent applications also. (5)

8 a) Discussing the case of propagation of em wave through a conducting medium, find the phase difference between electric and magnetic fields for good conductors. (7)

8 b) Explain the terms Linearly polarized wave and circularly polarized wave. Discuss the concept of polarization by reflection. (7)

Exam Code: 225502 **Paper Code: 2216**
(20)

Programme: Master of Science (Physics)
Semester-II

Course Title: Condensed Matter Physics-I

Course Code: MPHL-2393

Time Allowed: 3 Hours **Max Marks: 70**

NOTE: Attempt Five questions in all, selecting at least one question from each section. Fifth question may be attempted from any section. Each questions carry equal (14) marks.

Section A

1. (i) How the shortcomings of Einstein model were overcome by device model of specific heat? 4

   (ii) What is elastic stress and strain? Express them in terms of tensors notations. 10

2. (i) Derive Debey's equation for molar lattice specific heat both at lower and higher temperature. Discuss its arrangement with experimental results. 10

   (ii) Show that elastic constants are symmetrical $C_{ij} = C_{ji}$ 4

Section B

3. (i) Explain the phenomena of dislocation multiplications and slips. 7

   (ii) What is a grain boundary explain the Burger model of low angle grain boundaries. 7

4. (i) Distinguish between the formation of F-centre and V-Centre. 4

   (ii) Calculate the equilibrium concentration of Schottky defect and find the order of its magnitude. 10

Section C

5. State and derive the boltsman transport equation also describe its physical significance. 14

6. (i) What is activation energy? and find its expression for the formulation of defects in ionic crystals. 7

   (ii)Discuss the process of ionic conductivity in pure alkali halides qualitatively. 7

Section D

7. (i) Discuss dipolar polarisation in atoms and obtained and expression for it. 7

   (ii) Explain the dipole theory of ferroelectricity. 7

8. (i) State why the simple dipole theory fails to explain the ferro electricity? Suggest a theory which can explain the ferroelectric nature of Barium titrate.

10

(ii) Define Macroscopic Field and Lorentz field 4

Exam Code: 225502 Paper Code: 2217

Programme: Master of Science (Physics) Semester: II

Course Title: Atomic and Molecular Spectroscopy

Course Code: MPHL-2394

Time Allowed: 3Hours Max Marks: 70

Note: Attempt five questions in all, selecting atleast one question from each section. Fifth question can be attempted from any section. Each question carries 14 marks.

Section-A

1. Answer the following questions
   a. Explain the significance of spin-orbit interaction in the fine structure of hydrogen. Derive the expression for the fine structure energy correction due to spin-orbit interaction. (9)
   b. Derive the expression for Larmor Precession for an electron moving around a nucleus. Calculate the Larmor precession frequency for the electron's spin about the direction of the magnetic field of strength 1.5 T. (3, 2)

2. A. Define Lamb shift. Explain the experimental setup to observe the Lamb Shift. (5)
   B. Discuss the qualitative and quantitative intensity rules for doublets in atomic spectra. Provide examples to illustrate each rule. (4, 5)

Section-B

3. A. Define the Paschen-Back effect and explain how it differs from the Zeeman effect. Discuss the conditions under which the Paschen-Back effect becomes significant. (11)
   B. Calculate the Landé's factor (g-factor) for an electron with spin quantum number s = 1/2 and orbital quantum number l = 2 in LS coupling. (3)

4. A. Describe the external causes of line broadening. Explain the external effects, such as collision damping, pressure shift, and stark broadening contributing to spectral line broadening. (7)

B. Derive the expression for Landé's factor in LS coupling. Explain the significance of Landé's factor in predicting the behavior of atomic spectra. Calculate Lande's factor for the state ^2p. (7)

Section-C

5. Outline the principle of microwave spectroscopy in studying the rotational spectra of molecules. Derive the expression for the energy levels of a rigid rotor molecule. Discuss the experimental challenges and limitations associated with microwave spectroscopic analysis of liquid or solid molecules. (14)

6. Why the pure vibrational spectra of the molecules could not be observed? Describe the molecule as a vibrating molecule and draw the energy level diagram. Explain the transitions involved. Discuss the vibrational-rotational spectra of carbon monoxide. (14)

Section-D

7. Explain the quantum and classical theories of Raman Effect. Discuss the differences between the quantum and classical interpretations of Raman scattering phenomenon. Why stokes lines are more intense than antistokes lines? (14)

8. Explain the concept of dissociation energy and pre-dissociation energy for a diatomic molecule using the Fortrat diagram. Discuss the implications of these energies on the stability and reactivity of the molecule. (14)

Exam Code: 225504 | Paper Code: 4205

(20)

Programme: Master of Science (Physics) Semester-IV

Course Title: Particle Physics

Course Code: MPHL-4391

Time Allowed: 3 Hours | **Max Marks: 80**

Note: Attempt five questions, selecting at least one question from each section. The fifth question may be attempted from any Section. Each question carries 16 marks.

Section A

1. (a) Discuss the methods to determine the mass and lifetime of a muon. (12)

1. (b) How the lifetime of neutral pion is measured? (4)

2. (a) Explain four fundamentals forces of nature with an example in each case. Compare their range and strength. (10)

2. (b) Discuss the method to determine the mass of a charged pion. (6)

Section B

3. (a) What is strange about strange particles? How strangeness is assigned to these particles? (8)

3. (b) Which of the following interactions are forbidden? If forbidden, state the laws that are violated.

(i) $n + n \rightarrow n + \Sigma^0$ (ii) $\pi^0 \rightarrow \gamma + \gamma + \gamma$

(iii) $K^- \rightarrow n + e^-$ (iv) $n + n \rightarrow K + \Sigma^0$ (8)

4. Write various properties of quarks and anti-quarks. Construct the meson octet indicating the strangeness, charge, isospin and quark content of each meson. (16)

Section C

5. (a) What is the meaning of parity violation? (4)

5. (b) How Vector – Axial current interaction is responsible for the parity violation in beta-decay? (12)

6. (a) What is $\tau - \theta$ puzzle and how it was resolved? (8)

6. (b) How did GIM theory modify Cabibbo theory for neutral current weak interactions? (8)

Section D

7. What is spontaneous breaking symmetry? Discuss Higgs mechanism on the basis of spontaneous breaking symmetry. (16)

8. (a) What are Feynmann diagrams? Discuss the Feynmann rules to obtain matrix element of particle interactions. (16)

Exam Code: 225504 **Paper Code: 4206**
(20)

Programme: Master of Science (Physics)
Semester-IV

Course Title: Statistical Mechanics

Course Code: MPHL-4392

Time Allowed: 3 Hours **Max Marks: 80**

1. Attempt five questions, selecting at least one question from each section
2. Each question carry 16 marks
3. The fifth question may be attempted from any Section.

SECTION —A

1. (a) Derive equation of state of ideal gas and Discuss statistics of classical ideal gas in detail. (12 marks)
(b) Define Enthalpy Gibb's free energy, Helmholtz energy, Entropy (4 marks)
2. (a) Making use of the fact that entropy S(N,V,E) of a thermodynamic system is an extensive quantity, show that $N(dS/dT)_{V,E}+V(dS/dV)_{N,E}+E(dS/dE)_{N,V} = S$
(4 marks)
(b) Discuss the contact between statistics and thermodynamics and hence derive statistical parameters
(12 marks)

SECTION-B

3. (a) Discuss Virial theorem and Virial equation of state. (6 marks)

   (b)Define ensembles and discuss the statistics of micro canonical ensemble using example of classical ideal gas. (10 marks)

4. (a) Show that energy shared by the systems in a canonical ensemble follows a Gaussian distribution. Find the expression for dispersion. (8 marks)

   (b) Derive expression for grand partition function. (6 marks)

   (c) Define fugacity. (2 marks)

SECTION-C

5. Discuss the statistical thermodynamics of electron gas in magnetic field and hence discuss its contradictions. (16 marks)

6. (a) Discuss the canonical ensemble and GCE in quantum statistics. (12 marks)

   (b) Discuss Boltzmann formula in classical and quantum statistics" (4 marks)

SECTION-D

7. Discuss thermo dynamical behaviour of ideal Fermi gas in detail. (16 marks)

8. (a) Discuss the gas of phonons in detail. (8 marks)

   (b) Discuss Pauli paramagnetism in Fermi gas. (8 marks)

Exam Code: 225504 Paper Code: 4207

Programme: Master of Science (Physics) Semester - IV

Course Title: Radiation Physics

Course Code: MPHL-4393 (Opt. – II)

Time Allowed: 3 Hours Max Marks: 80

Note: Attempt five questions in all, selecting atleast one question from each section. Fifth question may be attempted from any section. Each question carries 16 marks.

Section A

1. Explain in detail the following:
   (a) Types and sources of ionizing radiation
   (b) Free air chamber and air wall chamber
   (c) Different radiation dose units (16)

2. Discuss in detail (a) Bragg Gray Principle
   (b) Absorbed dose and its measurement
   (c) Dose equivalent and quality factor (16)

Section B

3. Write a note on each of the following:
   (a) Pocket Dosimeter
   (b) Solid state Nuclear track detector (16)

4. Explain the working of film badge dosimeter and Neutron detectors. (16)

Section C

5. Explain the following terms:
   (a) Relative Biological effectiveness
   (b) Stochastic and non-stochastic effects
   (c) ALARA (16)

6. Explain the concept of (a) Radiation waste and its disposal
   b) Single target and Multi target theories in the context of radiation (16)

Section D

7. Discuss the following (a) Point Kernel technique
   (b) Exponential point Kernel technique (16)

8. Write a note on radiation attenuation calculations from a uniform plane source and also discuss time, distance and shielding rules. (16)

Exam Code: 225504 **Paper Code: 4208**

Programme: Master of Science (Physics) Semester-IV

Course Title: Material Science

Course Code: MPHL-4394 (Opt. – V)

Time: 3 Hours **Theory: 80**

Note: Attempt five questions in all, selecting at least one question from each section. The fifth question may be attempted from any section. Each question carries 16 marks.

Section A

1. Discuss in detail the process of Physical Vapor Deposition (PVD) and compare it with Chemical Vapor Deposition (CVD).
2. Discuss DC and RF sputtering techniques for thin film deposition, highlighting their working principles and applications.

Section B

3. Discuss the stress-strain behaviour of different types of polymers and its importance in engineering applications.
4. Compare thermosetting and thermoplastic polymers in terms of structure, properties, and applications.

Section C

5. Explain the principle, instrumentation, and applications of UV-Visible spectroscopy in materials characterization.
6. What is photoluminescence spectroscopy? Discuss its role in characterizing optical materials.

Section D

7. Discuss the principles of X-ray diffraction and how it is used to determine crystal structure.
8. Describe the principle, instrumentation, and applications of X-ray fluorescence spectroscopy.