PH 571.3 Reg No :

St Aloysius College (Autonomous)
Mangaluru
SEMESTER III - P.G. Examination - M.Sc Physics
November - 2024
QUANTUM MECHANICS II

Time : 3 Hours Max. Marks : 70

PART A

1 **Answer all questions choosing ONE from each unit.** (4x15=60)

Unit I

1 a. Show that product of norm of two vectors is always greater than or equal to the norm of their products. (9)

b. Consider a vector space spanned by the orthogonal basis $|e_1\rangle$, $|e_2\rangle$ and $|e_3\rangle$. Let there be two vectors in the space $|\alpha\rangle = i|e_1\rangle - 2|e_2\rangle - i|e_3\rangle$, $|\beta\rangle = i|e_1\rangle + 2|e_2\rangle$. Find all nine matrix elements of the operator $\hat{A} = |\alpha\rangle\langle\beta|$. Is this operator Hermitian? (6)

OR

2. a. What is uncertainty in measuring a quantity? Prove the general Heisenberg's uncertainty relation. (9)

b. Define inner product. What is projection of a vector? Explain the concept of projection operator. Show that $\sum_i \hat{P}_i = \hat{I}$ where $\hat{P}_i$ is the projection operator. (6)

Unit II

3. a. Arrive at $\hat{J}^2|jm\rangle = j(j+1)\hbar^2|jm\rangle$ and $\hat{J}_z|jm\rangle = m\hbar|jm\rangle$ for angular momentum $\vec{J}$. (9)

b. Explain the theory of addition of angular momenta. What are Clebsch-Gordan coefficients? (6)

OR

4. a. Arrive at $|\psi_n\rangle = \frac{1}{n!}(\hat{a}^\dagger)^n|\psi_0\rangle$ for linear harmonic oscillator. Also arrive at $E_n = (n+\frac{1}{2})\hbar\omega$. (9)

b. Suppose an electron is in a spin state $|\chi\rangle = A\begin{bmatrix} 3i \\ 4 \end{bmatrix}$, determine the normalization constant A and evaluate $\langle\hat{S}_x\rangle$, $\langle\hat{S}_y\rangle$ and $\langle\hat{S}_z\rangle$ in the state $|\chi\rangle$. (6)

Unit III

5. a. Show that there will be splitting of spectral energies when external electric field is applied on atoms. Explain using degenerate perturbation theory. (9)

b. What are turning points? What is classically forbidden region? How does WKB approximation give a solution to the case of transmission probability. (6)

OR

6. a. Using the trial wave function $\psi(x) = Ae^{-bx^2}$, estimate the ground state energy of a linear harmonic oscillator. (Given: $\int_{-\infty}^{\infty} x^{2n}e^{-bx^2}dx = \sqrt{\frac{\pi}{b}}\frac{2n-1}{(2b)^n}$). (8)

b. For time dependent perturbations arrive at the expression for transition probability for transition of a system from a lower energy state to a higher energy state by the absorption of energy. Also arrive at the Fermi's golden rule. (7)

Contd...2

Unit IV

7. a. Outline the steps involved in quantizing a classical field and hence arrive at the Euler Lagrange equations for a classical field. (7)
   b. Set up the Klein-Gordon equation for a relativistic particle. Show that the equation fails to explain the probability interpretation. (8)

OR

8. a. How did Dirac arrive at the concept of anti-particles? Explain with proof. (7)
   b. What are $\vec{\alpha}$ and β in Dirac's theory. What are their properties? (8)

PART - B

Answer any TWO questions. (2x5=10)

9. a) Show that operators that commute have simultaneous set of eigen vectors.
   b) Explain the Schrodinger picture.
   c) If $\hat{H} = \begin{bmatrix} 1 & \lambda \\ \lambda & 1 \end{bmatrix}$, and taking $\hat{H} = \hat{H}^{(0)} + \hat{H}'$ where, $\hat{H}^{(0)} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ and $\hat{H}' = \begin{bmatrix} 0 & \lambda \\ \lambda & 0 \end{bmatrix}$, find the exact eigen values of $\hat{H}$. Also find the first order corrections in energy eigen values considering $\hat{H}'$ as the perturbation and compare with actual results.
   d) What are the outcomes of solutions to Dirac's equation?

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PH 572.3 Reg. No: | | | | | | |

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Semester III – P.G. Examination – M.Sc. Physics

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CONDENSED MATTER PHYSICS II

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

PART - A

Answer all questions choosing one from each unit. **(15x4=60)**

UNIT -I

1. a) Elaborate First order phase transition in solids. **(6)**

   b) Explain the following terms, Line defect, Dislocation and Burger's vector with relevant sketches. **(9)**

OR

2. a) Define the following
   1.Thermoluminescence
   2.Electro luminescence
   3. Bioluminescence **(6)**

   b) What is an edge dislocation? Explain with the aid of a diagram. How it affect the strength of a solid? **(9)**

UNIT -II

3. a) Briefly discuss relevant theory of paramagnetism. **(6)**

   b) Discuss neutron diffraction technique using diagrams. **(9)**

OR

4. a) Explain Hund's rule and Lande's splitting factor. **(6)**

   b) Explain the molecular field Theory of ferrimagnetism. **(9)**

UNIT -III

5. a) What is Fourier transform? With the block diagram explain the working of a FTNMR spectrometer. **(9)**

   b) Compare and contrast MRI imaging with X-ray imaging. **(6)**

OR

6. a) Explain the influence of nuclear motion on NMR Spectra. **(6)**

   b) What is chemical shift and how it is measured? Find how many signals are obtained when the following samples are used? 1) CH_3OH 2) CH_3CH_2OH. Find their relative peak areas. **(9)**

UNIT -IV

7. a) Write a note on Elastic compliance and stiffness constants. **(6)**

   b) Derive Clausius Mossotti equation. **(9)**

OR

Contd...2

8. a) Write a note on the following

Polarisation

Dielectric constant.

Dielectric strength. (9)

b) Write a note on

Electronic polarisation

ionic polarisation (6)

PART - B

Answer any TWO questions: (2x5=10)

9. a) What is a color centre? Describe the action of F-centre.

b) Explain hysteresis of a ferromagnetic material using domain concept.

c) ESR spectrum of methyl radical occurs at 330 mT in a spectrometer operating at 9250 MHz. Calculate the 'g' value for the radical. Given Bhor magneton $\mu_B=9.274x10^{-24}$ J/T.

d) Write a note on Optical properties of ionic crystals.

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PH 573.3 Reg. No: | | | | | | |

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Semester III – P.G. Examination – M.Sc. Physics

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THERMODYNAMICS AND STATISTICAL PHYSICS

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

PART - A

Answer all questions choosing one from each unit. **(15x4=60)**

UNIT -I

1. a) At constant temperature, show that the internal energy of a van der Waals gas increases with the increase in volume of a system. **(6)**

   b) Obtain the heat capacity equation for pure substance and explain its importance. Write the heat capacity equation in terms of isentropic and isothermal compressibility. **(9)**

OR

2. a) Explain the term ensemble. Classify the three different ensembles and explain their salient features. **(6)**

   b) What are Characteristic functions? Derive the basic relations for characteristic functions U, H, A and G. Why are they referred to as thermodynamic potentials? **(9)**

UNIT -II

3. a) State and prove virial theorem in classical statistical mechanics. **(6)**

   b) Arrive at the Sachur- Tetrode equation and show how it resolves gibbs paradox. **(9)**

OR

4. a) State and prove Liouville's theorem. **(6)**

   b) Obtain the expressions for thermodynamical quantities of a monoatomic ideal gas using classical partition function. **(9)**

UNIT -III

5. a) Obtain the expression for degeneracy pressure of a degenerate electron gas. **(8)**

   b) Obtain the expression for the expectation value of a physical quantity in terms of the density operator. **(7)**

OR

6. a) Write a note on Lambda transition. **(6)**

   b) Discuss an ideal Bose gas, derive the equation of state, discuss BE condensation. **(9)**

UNIT -IV

7. a) State and prove the Nyquist theorem. **(9)**

   b) Discuss Fokker Planck equation. **(6)**

OR

8. a) Derive the Einstein relation connecting the mobility with the diffusion coefficient of a Brownian particle. **(9)**

   b) Briefly explain Langevin's theory. **(6)**

PART - B

Answer any TWO questions: **(2x5=10)**

9. a) Obtain second TdS equation using Maxwell relations.

   b) Write a note on ensembles.

   c) Under what conditions do BE and Fermi-Dirac distributions approach Maxwell-Boltzmann distribution? Represent graphically.

   d) Write a note on Fluctuations.

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PS 574.3 Reg No : | | | | | | | |

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RELATIVITY AND COSMOLOGY

Time : 3 Hours Max. Marks : 70

PART A

Answer ONE full question from each Unit (3x18=54)

Unit I

1 a) Write Lorentz transformation in tensor notation. What are four vectors? Define scalar product of four vectors. Define momentum four vectors. (9)

b) Derive expression for relativistic Doppler effect and aberration of t light. (9)

OR

2. a) Using the concept of invariant intervals of events, explain how spacetime diagrams can be constructed and how these diagrams can be used for studying motion of particles. (10)

b) Arrive at $E = mc^2$ and $E^2 = p^2c^2 + m_0^2c^4$ for a relativistic particle. (8)

Unit II

3. a) Arrive at the Einstein field equation from first principles. (10)

b) What are the properties of covariant derivatives? (8)

OR

4. a) Show that $\Gamma^{\lambda}_{\mu\nu}$ is not a tensor. (9)

b) Explain any two predictions of Einstein's theory of general relativity (9)

Unit III

5. a) Explain dark matter theory. What are the experimental observations that led to the prediction of its existence. (8)

b) Discuss various models of universe highlighting the explanation and proofs for the same. (10)

OR

6. a) Write the Robertson-Walker metric. What are open, closed and flat universes? How does this theory explain red shift of galaxies? (8)

b) What were the conditions that were prevalent in the early universe and also explain the various concepts like leptogenesis, baryogenesis and nucleosynthesis. (10)

PART - B

Answer any <u>FOUR</u> questions. (4x4=16)

7. a) Explain the motivation behind the formulation of theory of special relativity.

b) Explain steady state cosmology .

c) Explain the concepts spacetime, spacetime curvature.

d) Explain cosmological principle.

e) Show that $\frac{dE}{dp} = u$ for a relativistic free particle and also show that Newton's second law is invariant under Galilean transformation equations.

f) Explain Eötvös experiment that demonstrates the equality of gravitational and inertial masses.

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