CSM : 24

PHYSICS PAPER - II

Time Allowed : 3 hours Maximum Marks : 100

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instruction carefully before attempting questions)

There are eight (8) questions - four (4) questions each in Part A & B. Each question carries 20 marks.

Marks for each question is indicated against it.

Compulsory questions :

(a) Question No. 1 from Part-A and

(b) Question No. 5 from Part-B

[Compulsory questions No. 1 & 5 have 4 (four) Sub-questions carrying 5 marks each.]

Total No. of questions to be attempted :

5 (five) questions.

[A candidate shall attempt 2 (two) compulsory questions from Part A and B. Out of the remaining 6 (six) questions, 3 (three) are to be attempted taking at least 1 (one) but not more than 2 (two) questions from each Part]

Word Limit:

(a) Compulsory questions carrying 5 marks shall have a limit of 150 words.

(b) There shall be no word limit for the remaining questions.

PART - A

1. Answer the following questions: **(4×5=20)**

   (a) Explain the concept of wave-particle duality in quantum mechanics. How does the Schrödinger equation incorporate this duality?

   (b) Derive the expression for electrical conductivity on the basis of quantum free electron theory.

   (c) State Franck Condon principle. A molecule undergoes an electronic transition from the ground state to an excited state. The vibrational energy levels in the ground state are separated by 0.20 eV, while in the excited state they are separated by 0.15 eV. The electronic energy gap between the two states is 2.5 eV. During the transition, the molecule moves from the first vibrational level of the ground state (v = 1) to the second vibrational level of the excited state (v '=2). Calculate the energy of the absorbed photon during this transition.

   (d) Define fluorescence and phosphorescence, highlighting their key differences. Explain the underlying mechanisms of both processes and discuss their time scales.

2. (a) Solve the Schrödinger 's equation for a particle confined in a one-dimensional infinite potential well to obtain the wave functions and hence calculate the corresponding energy eigenvalues. Explain the physical significance of the quantization of energy levels in this system. What would happen to the energy levels if the width of the box is increased? **(6+3+1=10)**

   (b) A particle of mass *m* is confined in a one-dimensional finite potential well with depth V_0 and width *L*. Derive the expressions for the wave functions for the particle both inside and outside the well. Calculate the energy eigenvalues for bound states. How does the finite depth of the well affect the probability of finding the particle outside the well? **(6+3+1=10)**

3. (a) Solve the Schrödinger 's Equation for a Hydrogen atom using spherical polar coordinates and hence derive an expression for the energyeigen values of the Hydrogen atom. Explain the significance of the quantum numbers *n* (principal quantum number), *l* (orbital angular momentum quantum number), and m_l (magnetic quantum number) that arise from solving the equation. **(7+3=10)**

   (b) Describe the Stern-Gerlach experiment and explain how it demonstrates the concept of electron spin. In a Stern-Gerlach experiment, a beam of silver atoms is passed through a non-uniform magnetic field of gradient $\frac{dB}{dz} = 10^4$ *T/m*. Each silver atom has a magnetic moment $\mu = 9.27 \times 10^{-27}$ *J/T*, which is due to the spin of the unpaired electron. The silver atoms pass through a field region of length *L=10 cm* at a velocity of *v=500 m/s*. Calculate the force experienced by a silver atom in the magnetic field. **(7+3=10)**

4. (a) For a diatomic molecule modeled as a harmonic oscillator, derive the vibrational energy levels and explain the selection rules for vibrational transitions. **(6+4=10)**

(b) Describe the basic theory behind Nuclear Magnetic Resonance (NMR). What are the factors that influence the chemical shift in NMR spectroscopy? Discuss the basic difference of NMR with Electron Paramagnetic resonance (EPR). Give one significant application each of NMR and EPR in scientific research or industry. **(6+2+2=10)**

PART - B

5. Answer the following questions: **(4×5=20)**

(a) Write a short note on Mössbauer Spectroscopy.

(b) What are neutrinos? Discuss their key properties.

(c) Compare and contrast crystalline and amorphous structures of matter in terms of their atomic arrangement and physical properties with examples. Discuss how these differences affect their applications in various fields.

(d) Describe the working principle of solar cells and explain how they convert sunlight into electricity.

6. (a) What do you mean by the semi-empirical mass formula of a nucleus? Deduce expressions for the different terms of the semi-empirical mass formula. **(2+8=10)**

(b) What do you mean by Q-value of a nuclear reaction? Deduce an expression for Q-value of a nuclear reaction in terms of the masses of the reactants and products of the reaction. Calculate the Q-value of the reaction $^{12}C + n \rightarrow {}^{13}C + \gamma$, given the following atomic masses: $m\,(^{12}C)=12.0000\,u$, $m\,(n)=1.0087\,u$, $m(^{13}C)=13.0034\,u$ and $m(\gamma)=0\,u$.
(1+4+3=8)

(c) Briefly discuss the working of a nuclear power reactor. **(2)**

7. (a) Discuss the different crystal systems and their respective space groups. **(7)**

(b) Distinguish between Type I and Type II Superconductors. **(3)**

(c) Discuss the band theory of solids and its significance in classifying materials as conductors, insulators, and semiconductors. **(10)**

8. (a) With a neat diagram, describe the working of a n-p-n bipolar junction transistor. Draw the circuit diagram of a n-p-n transistor in Common Base configuration and discuss the different characterisitcs.
(3+7=10)

(b) Give comparisons between the characteristics of an ideal Op-amp and practical IC741 Op-amp. With the help of appropriate ciruit diagrams explain how an Op-amp can be used as an inverting and non inverting amplifiers. **(4+6=10)**

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