Maximum Marks: 60  
Credits: 04  
Duration: Three Hours

"Students of Advanced P.G. Diploma in Nanotechnology will be examined out of 75 marks and their obtained marks shall be proportionately raised."

Answer all the questions. Notations used have their usual meaning.

1(a) Discuss Schrodinger equation for electron states in bulk crystalline lattices and write expression for eigen values by considering ‘parabolic band approximation’. Explain the concept of quantum confinement that leads to realisation of photoluminescent quantum dots.

1(b) Discuss colloidal growth method and ion implantation method for manufacturing semiconductor quantum dots.

OR

1(b') Define density of states (DOS) and deduce expression of DOS for 3D, 2D, 1D, and 0D materials and draw graphs of DOS Vs. E in all the cases.

2(a) Discuss the principle of a time of flight type mass spectrometer for determining size of nanoparticles.

2(b) Write a note on the discoveries of C_{60} and CNT.

2(c) Discuss the classification of CNTs on the basis of chiral angle (θ). Explain the structure of a SWCNT and deduce the expressions for tanθ and diameter of CNT.

3(a) What do you understand by ‘self assembly’ and ‘SAM’?

3(b) Describe the mechanisms of growth of semiconductor islands.

3(c) Explain the formation of SAM of alkane thiol on gold substrate.

4(a) With the help of a neat diagram explain the structural differences between a plant and animal cells.
4(b) Explain the terms gene, genome, genetic code, and protein biosynthesis. What is central dogma of life?

OR

4’(a) Write the names of all standard amino acids found in human body and explain why protein is called nanowire?

4’(b) Define packing parameter \( p \) of a surfactant molecule and draw the structures formed by amphiphillic molecules at water-oil or water-air interfaces for various values of packing parameter.
2013-14
M.TECH. (WINTER SEMESTER) EXAMINATION
NANOTECHNOLOGY
QUANTUM MECHANICS
AP-611

Maximum Marks: 60 Credits: 04 Duration: Three Hours

Note: i) Answer all the questions. ii) Notations used have their usual meanings.

1(a) Find the discrete energy levels of a particle in a one-dimensional finite square well potential defined by

\[ V(x) = \begin{cases} 0, & \text{for } -a \leq x \leq a \\ V_0, & \text{otherwise} \end{cases} \]

Show that in the limiting case of \( V_0 \to \infty \), the energy levels correspond to that of infinite square well.

1(b) A harmonic oscillator is in the ground state. (i) Where is the probability density maximum? (ii) What is the value of maximum probability density?

1(c) A 1-eV electron got trapped inside the surface of a metal. If the potential barrier is 4.0 eV and the barrier is 2 Å wide, calculate the probability of its transmission.

2(a) For Pauli’s matrices, prove that: (i) \([\sigma_x, \sigma_y] = 2i \sigma_z\) and (ii) \(\sigma_x, \sigma_y, \sigma_z = i\).

2(b) For a spin-1/2-system, Derive the matrices for \(S_x, S_y,\) and \(S_z\). List their eigen-values with the corresponding eigenvectors.

2(c) Discuss free electron theory of metals.

3(a) Obtain the secular equation by using the variation approximation method. Write at least two applications of this method.

3(b) Discuss briefly the electron density of states.

3(c) An electron has a speed of 600 m/s with an accuracy of 0.005%. Calculate the uncertainty with which we can locate the position of the electron. (Given data: \(h = 6.6x10^{-34}\) J, \(m = 9.1x10^{-31}\) kg.)

3'(a) An electron is subjected to a potential \(V(x) = -e^2/4x\). Write the Schrödinger equation and obtain the ground state energy.

3'(b) Show that the zero point energy \(\frac{\hbar \omega}{2}\) of a linear harmonic oscillator is a manifestation of the uncertainty principle.

4(a) What are adiabatic and sudden approximations in the time dependent perturbation theory and under what conditions are these valid? Illustrate your answer by suitable examples.

4(b) What is a Quantum Computer? Discuss its salient features.
2013-2014
Autumn Semester (I Semester) Examination
M.Tech. Nanotechnology and Advanced P.G. Diploma in Nanotechnology
Physics and Chemistry of Solids
AP-612

Maximum Marks: 60
Duration: Three Hours

(“Students of Adv. P.G. Diploma in Nanotechnology will be examined out of 75 marks and their obtained marks shall be proportionately raised.”)

Answer all questions. The symbols used have their usual meaning.

1(a) Define primitive and non-primitive translation vectors. Obtain the primitive translation vector of hexagonal close packed (hcp) structure and hence find out the non-primitive unit cell volume and the primitive unit cell volume of hcp structure. [4]

1(b) How does a crystal differ from a lattice? Draw the diamond crystal structure. The diamond crystal structure has the cubic edge of 0.356 nm. Calculate the distance between the first nearest neighbours and the number of atoms per cm³. [4]

1(c) Show that minimum cation to anion radius ratio for coordination number 3 is 0.155. [3]

1(d) A narrow beam of x-rays with wavelength 0.15 nm is reflected from an ionic crystal with a fcc structure having a density of 3.32 g/cm³ and the molecular weight 108 amu (1 amu = 1.66x10^-24 g). Find out the lattice constant and sine of angle corresponding to (111) reflection. [4]

2(a) Write down different types of bonding in solids. Van der Waals force can hold the inert gas atoms together to form solids at low temperature, but they cannot hold such atoms together to form molecules in the gaseous state. Why? Show that interatomic force in case of Van der Waals interaction is proportional to r^{-7}. Give U(r) vs. r and F(r) vs. r representation. [6]

2(b) Why does solid expand on heating? Write down the properties of ionic crystal and obtain the Madelung constant per molecule of 3 dimensional NaCl crystal. [5]

2(c) (i) If the ionization energy of potassium and the electron affinity of chlorine are 4.34 eV and 3.61 eV respectively. The Madelung constant of KCl structure is 1.748 and the distance between ions of opposite sign is 0.314 nm. Compute cohesive energy of KCl. [4]

(ii) The observed cohesive energy of KCl is 6.42 eV per ion pair which differs from

Contd......2
result obtained in (i) above. Why does this discrepancy occur? Find out the exponent ‘n’ in the formula Br\(^{-n}\) for the potential energy arising from this source.

3(a) Discuss Fermi-Dirac distribution function at absolute zero temperature below and above Fermi energy \(E_F\). Obtain an expression for carrier concentration at equilibrium in conduction band in case of a semiconductor.

3(b) On the basis of applications, categorize ceramic materials. What are the refractory ceramics and write some of their uses?

**OR**

3(b') What are composite materials? Mention the advantages and limitations of these materials?

3(c) Calculate \(N_c\) and \(N_v\) in the case of GaAs at 300 K. Also evaluate intrinsic carrier concentration and compare with the given intrinsic carrier concentration. (Given: \(m_e^* = 0.067\ m_0\), \(m_p^* = 0.48\ m_0\), \(E_g = 1.43\) eV, \(k_B = 1.38 \times 10^{-23}\) J/K, \(n_i = 2 \times 10^6\) cm\(^{-3}\) and \(h = 6.63 \times 10^{-34}\) Js)

4(a) What are different defects in solids? Derive an expression for equilibrium concentration of Schottky defects and discuss its dependence on temperature.

4(b) Discuss development of planar imperfections with the help of suitable diagrams.

4(c) The energy for vacancy formation in the Ge crystal is 2.2 eV. Calculate vacancy concentration in Ge at 938 \(^0\)C. [Given: \(M_a = 72.64\) g/mol, \(\rho = 5.32\) g/cm\(^3\) and \(N_A = 6.023 \times 10^{23}\) mol\(^{-1}\)].
Maximum Marks: 60  Credits: 04  Duration: Three Hours

**Note:**
- i) Students of Adv. P.G. Diploma in Nanotechnology will be examined out of 75 marks and their obtained marks shall be proportionally raised.
- ii) Answer all the questions.
- iii) Notations used have their usual meanings.

1(a) With the help of suitable diagram briefly discuss the electric arc deposition technique to synthesize CNT. [04]

1(b) What do you mean by ablation? What is the difference between laser ablation and laser pyrolysis technique to synthesize nanomaterials? [04]

**OR**

1(b') With the help of necessary diagrams briefly discuss the fundamental sequential steps that occur in every CVD process. [04]

1(c) What is plasma? How is it being created in the case of sputtering process? Why insulating film cannot be deposited through DC sputtering process? [04]

2 Describe any three of the following synthesis methods of obtaining nanoparticles; [3x4]
   a) Thermolysis route  
   b) Electrochemical synthesis  
   c) Sol-gel method  
   d) Solvated metal atom dispersion (SMAD)  
   e) Sonochemical route.

3(a) Write five scientific names of commonly used microorganisms which can be used for the synthesis of metal nanoparticles. [2.5]

3(b) Explain the mechanisms employed by the bacteria and fungi for the synthesis of metal nanoparticles. [5.5]

3(c) Describe the advantages of the biosynthesis of nanoparticles. [04]

4(a) Mention the names of various types of XRD line broadenings. Show that particle size, t is given by the relation:

\[ t = \frac{0.92}{\beta \cos \theta} \]  

[assume the particles size to be less than 1000 Å] [03]
4(b) What is a spectrophotometer? Discuss in brief how this equipment can be used for determining the band gap of a semiconductor.

4(c) With the help of a diagram briefly discuss the dark field and bright field images of TEM.

5(a) What do you mean by lithography? Discuss the basic steps of photolithography to design a pattern as shown in the figure.

5(b) What do you mean by resolution of a lithographic process? Discuss in brief the factors that affect the resolution in the case of photolithography and X-ray lithography.

OR

5(b') Discuss e-beam lithographic process and the proximity effect in it.

5(c) Differentiate between focused ion beam (FIB) and e-beam lithography? Discuss three fundamental mechanisms that can provide patterning in FIB.