2014-15
M.TECH. AUTUMN SEMESTER (I SEMESTER) EXAMINATION
M.Tech. and Advanced P. G. Diploma in Nanotechnology
FUNDAMENTALS OF NANOTECHNOLOGY
AP-610

Maximum Marks: 60
Credits: 04
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 the questions. Notations used have their usual meaning.

1(a) Write a note on important points in Feynman's lecture where he predicted emergence of a new technology. Differentiate between 'Top Down' and 'Bottom Up' approaches. [05]

1(b) What is Lycurgus Cup? Where is it located? What is its important attribute? [02]

1(c) Write a note on natural nanomaterials. [04]

1(d) Define a nano-meter and compare this with other length scales. [02]

1(e) What is the effect of size? [02]

2(a) Define the process of self assembly. [05]

2(b) Discuss the three processes of semiconductor island formation. [05]

2(c) Discuss the formation of alkane thiol SAMS and write their applications. [05]

3(a) Describe discovery and important applications of Carbon-60. How many pentagons/hexagons will be added in going from C60 to C70 and C80? [05]

3(b) Draw the figure of a graphitic monolayer, showing the axis (T), the circumferential vector (Ch) and chiral angle (θ). How can a CNT be constructed and what will be the expression for diameter of the CNT and tanθ? [05]

3(c) Compare properties of CNT with other materials and write some important applications. [05]

4(a) With the help of a neat diagram explain the secondary structure of DNA. Differentiate between DNA and RNA. [05]

Contd ... 2.
4(b) What are self-assembling peptides? How are they used to build nanostructures in a bottom-up approach?

OR

4'(b) Define packing parameter $p$ of a surfactant molecule and draw the structures formed by amphiphilic molecules at water-oil or water-air interfaces for various values of packing parameter $p$.

4(c) What is protein biosynthesis? Explain the role of ribosomes in protein synthesis with a suitable diagram.
2014-2015
AUTUMN SEMESTER (I-SEMESTER) EXAMINATION
M.TECH. NANO-TECHNOLOGY
QUANTUM MECHANICS
AP-611

Maximum Marks: 60
Duration: Three Hours

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

1 (a) Consider a particle of mass moving in a one dimensional potential specified by

\[ V(x) = \begin{cases} 0, & -2a \leq x \leq 2a \\ \infty, & \text{otherwise} \end{cases} \]

Find the energy eigen values and eigen function.

1 (b) A Particle of mass m and charge e moving in a one dimensional harmonic potential is subjected to an electric field e in the x-direction. Find the energy levels and eigen functions.

1 (c) An electron has a speed of 500 m/s with an accuracy of 0.004%. Calculate the certainty with which we can locate the position of the electron. (Given, \( h = 6.63 \times 10^{-34} \) Js, \( m = 9.11 \times 10^{-31} \) kg)

2 (a) Find the transmission probability for a particle incident on a one-dimensional potential barrier of height \( V_0 \) and width \( a \). Consider the cases when the energy of the particle (a) \( E > V_0 \) and (b) \( E < V_0 \).

2 (b) Show that the zero point energy of \( \frac{1}{2} \hbar \omega \) of a linear harmonic oscillator is a manifestation of the uncertainty principle.

3 (a) The definition of angular momentum given by \( L = r \times p \) is not a general one. Why? Define a general angular momentum operator.

3 (b) Outline the time independent perturbation theory applicable for the stationary state problem and deduce expression for the first order perturbation correction when the energy levels of the unperturbed state are non-degenerate.

3 (c) Discuss briefly the free electron theory of metals.

Continued........2
4 (a) Explain the terms quantum Entanglement and quantum decoherence. Discuss the future outlook of quantum computers.

4 (b) Explain briefly the principle of time-dependent perturbation theory and mention a few applications of this theory.

4 (c) Obtain the ground state energy of a one-dimensional harmonic oscillator of mass \( m \) and angular frequency \( \omega \) using a Gaussian trial function.

OR

4 (c') Obtain the energy eigenvalues of harmonic oscillator by the WKB methods.

OR

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

4'(b) State Pauli's spin matrices and their eigenvectors. For Pauli's spin matrices, prove the following relations.

(i) \( \sigma_x^2 = \sigma_y^2 = \sigma_z^2 = 1 \).

(ii) \( \sigma_x\sigma_y = i\sigma_z, \sigma_y\sigma_z = i\sigma_x, \sigma_z\sigma_x = i\sigma_y \).

4'(c) The WKB method is valid for systems in which the potential is slowly varying. Why?
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 the terms; crystalline, polycrystalline, single crystalline and amorphous state of matter. Why most of the solids are crystalline in nature? What do you mean by atomic packing fraction? Calculate the atomic packing fraction of hexagonal close packed structure.

1(b) What do you mean by relative interplanar spacing? Prove that relative interplanar spacing for simple cubic crystal of side ‘a’ is given by \( d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}} \). An orthorhombic crystal whose primitive translation vectors are \( a = 1.21 \text{Å}, b = 1.84 \text{Å} \) and \( c = 1.97 \text{Å} \). If a plane with Miller indices \( (231) \) cuts an intercepts of \( 1.21 \text{Å} \) along the x axis, find the length of intercepts along y and z axes.

1(c) Determine the wavelength of diffracted beam when a beam of x-rays having wavelengths in the range 0.2Å to 1Å incident at an angle \( \theta \) with cube face of rock salt structure and hence find out the ratio of first four wavelengths of the diffracted beam.

2(a) What do you mean by cohesive energy? Calculate the cohesive energy of NaCl from the following data: Madelung constant of NaCl crystal(\( \alpha \)) = 1.748, \( n = 9 \), \( r_0 = 2.81 \text{Å} \), ionization energy of Na = 5.14eV and electron affinity of Cl = 3.61eV.

2(b) Consider a line of \( 2N \) ions of alternating charge \( \pm e \) with a repulsive potential energy \( \frac{A}{r^n} \) between nearest neighbours. Show that the minimum energy at equilibrium separation is

\[
U(r_0) = -\frac{N e^2 2 \log 2}{4\pi e_0 r_0} \left(1 - \frac{1}{n}\right)
\]

2(c) Distinguish between ionic and covalent bonds. Explain the metallic bonds. What is the nature of bond in NaCl and diamond structure?
2(d) Write a short note on hybridization and molecular orbital theory for a diatomic molecule.

3(a) What are the postulates of Drude model? Obtain an expression for electrical conductivity in terms of mobility for metals and also establish relation of electrical conductivity with temperature. What are the limitations of this model?

OR

3(a') Starting with equilibrium concentrations electrons n₀ and holes p₀ in their respective bands, obtain an expression for intrinsic carrier concentration and discuss its dependence on temperature.

3(b) What are the ceramic materials? Classify ceramics and discuss one of the ceramic in detail along with its applications.

OR

3(b') What is the importance of composites in aircraft industry? Mention few important characteristics and limitations of these materials.

3(c) Explain why Si doped with 10¹⁴ cm⁻³ Sb is n-type at 400 K but similarly doped Ge not. Given for Si→ \( m_n^* = 1.1 m_0, m_p^* = 0.56 m_0, E_g = 1.09 \text{ eV}, k_B = 1.38 \times 10^{-23} \text{ J/K} \)

Ge→ \( m_n^* = 0.55 m_0, m_p^* = 0.37 m_0, E_g = 0.63 \text{ eV}, h = 6.63 \times 10^{-34} \text{ J.s} \)

4(a) Categorize imperfections in solids on the basis of their dimensionality. What do you understand by Frenkel defects? Derive an expression for Frenkel defect concentration in an ionic solid and discuss its dependence on temperature.

4(b) Discuss development of line imperfections with the help of suitable diagrams. What is the reason behind the low observed strength of single crystals as compared to the theoretically predicted strength?

4(c) Calculate the number of Schottky defects/m³ in KCl at 300 °C. The energy required for Schottky defect formation is 2.5 eV, while density for KCl (at 300 °C) is 1.995 g/cm³. [Given: \( M_{\text{at}}(\text{K}) = 39.10 \text{ g/mol}, M_{\text{at}}(\text{Cl}) = 34.45 \text{ g/mol and } N_A = 6.023 \times 10^{23} \text{ mol}^{-1} \)]
maximum marks: 60

students of adv. p.g. diploma will be examined out of 75 marks and their obtained marks shall be proportionally raised.

answer all the questions. notations used have their usual meanings.

1(a) What do you understand by the terms empirical and thermodynamic temperatures?

(b) show by citing an example that a reversible process is always quasistatic while a quasistatic process does not always need to be reversible.

(c) how are the micro- and macro-states of a system defined? give the statement of the ergodic hypothesis.

(d) What is an ensemble and its various classifications? When an ensemble is said to be in statistical equilibrium?

(e) what are important consequences of second law of thermodynamics?

2(a) what is entropy of mixing? derive an expression for it in case of mixing of distinguishable and non-interacting particles. how does it result in the gibb's paradox?

(b) a copper bar is in thermal contact with a heat reservoir at 127°c at one end and another heat reservoir at 27°c at the other end. if 1200 j of heat is conducted through the rod calculate the entropy change for the process. does the entropy of rod will change?

(c) explain the terms phase space and phase space density. show that phase space density remains constant as the system/ensemble evolves among its possible microstates.

3 Discuss Bose-Einstein(BE) statistics. With the help of a block diagram show all the possible macro-states of a system of 6 particles having an energy of 6 units obeying BE statistics. The degeneracy of each energy level of this system is 3. Also calculate the thermodynamic probability of this system and average occupation number of the second and ground level.

or

3' Discuss Fermi-Dirac(FD) statistics. Obtain an expression for the thermodynamic probability of a system obeying this statistics. Also obtain an expression for FD distribution function. Cite some examples of the system obeying this statistics.

continued......2
4(a) Define Diffusion flux. State and explain steady and non steady state diffusion processes in solids. [05]
(b) Write short note on Kirkendall effect in solids. [02]
(c) In order to harden the titanium slab by the diffusion of carbon, what will be the diffusion coefficient if the concentration of a carbon at 1mm into the surface of the titanium slab is 0.33kg/m^3 and at 4mm the concentration is 0.76kg/m^3. Suppose the temperature of the carburizing environment is 925°C, and the rate at which carbon is entering this 3mm thick region is 1.27x10^-9kg/m^2s. [03]

5(a) Distinguish between homogeneous and heterogeneous nucleation. Derive an expression for the nucleation rate (N) in case of homogeneous nucleation. [06]
(b) Describe the mechanism by which Martensite is formed. [03]
(c) For the solidification of a pure Gold; Calculate the critical radius r* and the activation energy ΔG* if nucleation is homogeneous? It is given that latent heat of fusion, surface free energy and super cooling temperature (ΔT) are -1.16x10^9 J/m^3, 0.326J/m^2 and 230K respectively. (Melting point of Gold is 1046°C). Note: erf(z) = 0.3794, 0.4284 at z = 0.35, 0.40 respectively. [04]

6 (a) Show that for an ideal binary solution molar free energy of mixing is given by
\[ ΔG_M = N_a kT \left[ (1-x) \ln \left \{1-x \right \} + x \ln \{x\} \right], \]
where N_a is the average concentration of atoms, K is the Boltzmann’s constant and T is the temperature. [03]
(b) What is an electrochemical process? Illustrate with an example. [02]
Maximum Marks: 60 Duration: Three Hours

Note: i) Answer all the questions. Symbols used have their usual meanings.
   ii) Students governed by the old ordinance will be examined out of 75 marks and their obtained marks shall be raised proportionally.

1(a) Explain the principle, working and advantages of high energy ball milling technique. [04]

OR

1'(a) With the help of neat diagram, explain molecular beam epitaxy (MBE) method to prepare nanoparticles. [04]

1(b) Describe synthesis of nanostructure by chemical vapour deposition (CVD) technique and give its limitations. [04]

1(c) Discuss the working principle and advantages of DC & RF sputtering techniques. [04]

2. Describe any three of the following methods for synthesis of nanoparticles. [12]
   (i) Sol-gel method (ii) Electro-chemical method (iii) Metal nanocrystal by reduction method (iv) Photochemical synthesis method (v) Thermolysis route method

3(a) Give a brief introduction of the biosynthesis of nanoparticles and mention its advantages. [04]

3(b) Write two names of different types of bacteria, fungi and yeast commonly used for the synthesis of metal nanoparticles. [03]

3(c) Describe in detail any one of the following: [05]
   (i) Role of bacteria in metal-nanoparticles synthesis
   (ii) Role of fungi in metal-nanoparticles synthesis

4 What are scanning probe microscopes? Name any two of such microscopes. Describe the principle and working by giving the details of different operation modes of an atomic force microscope (AFM). Also mention its advantage over a STM. [12]

OR

4'(a) Discuss the working principle of electron microscopes. Give a comprehensive description of a scanning electron microscope (SEM). Mention some salient features that make SEM different from TEM. [09]

4'(b) What wavelength (in nanometres) is expected to be associated with an electron accelerated from rest through a potential difference of 300 kV? Name the microscope that uses the electrons of such wavelengths. [03]

5. Give the detailed accounts of i) masks and ii) resist materials (positive & negative both) used in nanolithography techniques. Name at least three nanolithography techniques and discuss one of these in detail. [12]