College of Engineering Pune

Wellesley Road Shivajinagar Pune, Pune-5

Engineering Physics II (NE) : End-Semester Exam May-2012

Semester II, F.Y.B.Tech — Date: 8 May 2012

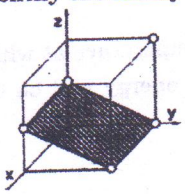
Time: 3hrs — Max marks: 50

All questions are compulsory. — Unspecified symbols carry their usual meaning.

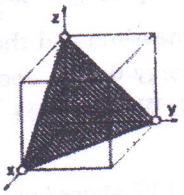
PHYSICAL CONSTANTS

Free space permeability $\mu_0 = 4\pi \times 10^{-7}$Vs(Am)$^{-1}$	Speed of light in vacuum $c = 3 \times 10^8$ms^{-1}
Gas const. $R = 8.314$Jmole^{-1}K^{-1}	Boltzmann const. $k_B = 1.38 \times 10^{-23}$JK^{-1}
Electron mass$= 9.1 \times 10^{-31}$kg	Planck's const. $h = 6.626 \times 10^{-34}$Js
Avogadro's No. $N_A = 6.023 \times 10^{23}$/mole	1eV $= 1.602 \times 10^{-19}$J

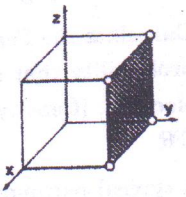
1. (a) Identify the family of planes to which the shaded planes belong. **3 MARKS**



i)



ii)



iii)

(b) Si wafer is doped with 10^{21} phosphorus atoms/m^3. Calculate i) concentration of majority carriers, ii) minority carrier concentration and iii) electrical resistivity at 300 K. ($n_i = 1.5\times10^{16}$/m^3 at 300 K, mobility of holes and electrons are 0.035 and 0.048 m^2/V-s respectively). **3 MARKS**

(c) Derive an expression for the density of states of electrons trapped in cubic metal of side L whose energy is given as $E_{n_x,n_y,n_z} = \frac{h^2}{8mL^2}(n_x^2 + n_y^2 + n_z^2)$, where n_x, n_y, n_z are +ve integers. Find the number of states available for electrons in a cube of side 0.05 cm with energy$\leq$ 1eV. **4 MARKS**

OR

(c) Using appropriate diagram, show that the packing factor for FCC lattice is $\frac{\pi}{3\sqrt{2}}$. Calculate the density of Cu (FCC structure, lattice constant = 3.615Å and At. wt. = 63.5) **4 MARKS**

2. (a) For lead $T_c = 7.26$K and $H_c = 8 \times 10^5$A/m. What is the maximum temperature at which lead can be used as a superconductor in the presence of a magnetic field of 4×10^4A/m ? **3 MARKS**

(b) Energy of the n^{th} level of H atom is $E_n = -\frac{13.6}{n^2}$eV and the degeneracy is n^2. At what temperature is the population of the 1^{st} excited state of hydrogen i) half the ground state population? ii) same as the ground state population? iii) twice the ground state population? **3 MARKS**

(c) If the energy of a solid is, $U = 9N_Ak_BT\left(\frac{T}{\theta_D}\right)^3\int_0^{\frac{\theta_D}{T}}\frac{x^3dx}{e^x-1}$ where $x = \frac{h\nu}{kT}$ and θ_D: Debye temperature, obtain the expressions for specific heat for $T \to 0$ and $T \to \infty$. $\left(\int_0^\infty \frac{x^3dx}{e^x-1} = \frac{\pi^4}{15}\right)$. **4 MARKS**

OR

(c) Show that magnetization of a paramagnetic material is given by $M = N\mu_m\left[coth\left(\frac{\mu_m B}{k_BT}\right) - \frac{k_BT}{\mu_m B}\right]$, where μ_m is the atomic dipole moment. **4 MARKS**

3. (a) Sketch the graphs showing the magnetic field and temperature dependence of magnetization for diamagnetic and paramagnetic materials. **4 MARKS**

(b) A system consisting of N spatially separated sub-systems, is in thermal equilibrium with a heat reservoir at absolute temperature $T = \frac{\epsilon}{k_B}$ where ϵ is the energy. If each sub-system has non-degenerate energy levels of energy 0 and ϵ, find i) the partition function, ii) the mean energy, and iii) the entropy, of the system. **3 MARKS**[1]

[1]PTO

(c) Iron has a FCC structure with lattice constant of 0.287 nm and Young's modulus $Y = 22 \times 10^{10}\text{N/m}^2$. If iron melts when the average amplitude of its atomic vibrations is 9.8% of the inter-atomic spacing a, compute the melting point of iron. (The force constant for each oscillator is given by $Y \times a$) **3 MARKS**

OR

(c) Show that the heat required for raising the temperature of copper from absolute zero to 0.0269 K is 2.52 erg and increase in entropy is $1.88 \times 10^{-5}\text{JK}^{-1}$. Assume constant volume and $C_v = 7 \times 10^{-4}T\left[\text{JK}^{-1}\right]$, where T is the absolute temperature. **3 MARKS**

4. (a) If a change dx in an external parameter X, causes a change dE in the energy of a canonical system, derive the expression for average work done dW in terms of partition function Z. Show that the mean pressure,$\langle P\rangle = k_B T\frac{\partial \ln Z}{\partial V}$. **4 MARKS**

(b) Calculate wavelength of atomic vibrations at υ_D in copper and compare it with lattice constant= 3.615Å. Use, $\theta_D = 348\text{K}$ and sound speed $v_s = 4000\text{m/s}$. **3 MARKS**

(c) Calculate the Fermi energy of potassium and then find the temperature at which there is 1% probability that a state with energy 0.4 eV above the Fermi energy will be occupied by an electron. {Density: 8600kg/m^3, At. Wt.= 39.202 } **3 MARKS**

OR

(c) A typical paramagnetic solid has 10^{28} atoms/m^3. The magnetic moment of each atom is $1.8 \times 10^{-23}\text{Am}^2$. Calculate the paramagnetic susceptibility at 300K. What would be the dipole moment of a bar of this material 0.1m long and having a cross section of 1cm^2 placed in a magnetic field of $8 \times 10^4\text{A/m}$? **3 MARKS**

5. (a) In aluminum, sound speeds are $v_l = 6.32 \times 10^3\text{m/s}$ and $v_t = 3.1 \times 10^3\text{m/s}$. i) Calculate Debye cut-off frequency, υ_D. ii) Find υ_D from Debye temperature 375 K. {Density: 2700kg/m^3, At. Wt.= 26.97 } **4 MARKS**

(b) Air at sea level consists of 78% nitrogen and 22% oxygen by volume (neglecting other gases). Find the % content of these gases in air at an altitude of 8.75 km. Assume $T = 300\text{K}$, mass of $O_2 = 53.44 \times 10^{-27}\text{kg}$ and mass of $N_2 = 47.76 \times 10^{-27}\text{kg}$. **3 MARKS**

(c) Determine mean potential energy of an ideal gas molecule in thermal equilibrium at T contained in cubical box of side L. Assume that the only external field acting on the gas molecule is the earth's uniform gravitational field, neglect kinetic energy of the gas molecule. **3 MARKS**

OR

(c) In a canonical ensemble the entropy, $S = k_B\left(\beta\langle E\rangle + lnZ\right)$ where$\beta = \frac{1}{k_B T}$. Establish the relation between S and probability of occupancy P_r, where 'r' is an accessible state of a system. Further show that at absolute zero temperature if non degenerate ground state is the only accessible state for a system, the entropy of the system becomes zero. **3 MARKS**