2018

PHYSICS

PHY 305

CONDENSED MATTER PHYSICS-II

Full Marks: 80

Time: 3 hours

The figures in the margin indicates full marks for the questions :

1. Answer the following questions. 1x5=5

a) A p-type semiconductor material is doped with _____ impurities whereas a n-type semiconductor material is doped with _____ impurities

(i) acceptor, donor (ii) acceptor, acceptor

(iii) donor, donor (iv) donor, acceptor

b) The superconducting state is perfectly _____ in nature

(i) Diamagnetic (ii) Paramagnetic

(iii) Ferromagnetic (iv) Ferrimagnetic

c) A photodiode is operated in

(i) Forward biased condition

(ii) Reverse biased condition

(iii) Both forward and reverse biased condition

(iv) No biased condition

d) What do you understand by the term phonon? Which statistics does it obey?

e) Explain the term Pauli paramagnetism.

2. Answer the following 2x5=10

a) What is Frohlich's electron-phonon interaction?

b) Discuss how cooper pairs are formed in superconductors.

c) A p-n diode at a temperature of 25° C has V_D = 0.5V. If the reverse saturation current is 10 fA, calculate the diode current.

d) Explain the role of phonon momentum in Normal and Umklapp process using relevant diagram.

e) The reflectivity of single crystal silicon at 514.5 nm is 40% and absorption coefficient is 3.8 x 10^5 m^{-1}. Calculate the transmission of a sample with a thickness of 10 μm.

3. Answer the following questions (any five) 5x5=25

a) A Si solar cell has short circuit current of 100 mA and an open circuit voltage of 0.8 V under full illumination. What is the maximum power delivered by this cell if the fill factor is 0.7? Find the efficiency if the incident light intensity is 1000 W/m^2. 5

b) An abrupt Si p-n junction with cross section area $A = 0.001\ cm^{-2}$ has $N_a = 10^{15}\ cm^{-3}$ on one side and $N_d = 10^{17}\ cm^{-3}$ on the other. Calculate the following 5

i. Contact potential v_o at room temperature

ii. Space-charge width at zero bias voltage

iii. Space-charge width at forward bias voltage 0.5 V.

(Consider for silicon, $\varepsilon_r = 12$, $n_i = 1.5 \times 10^{10}\ cm^{-3}$ and $\varepsilon_o = 8.85 \times 10^{-12}\ F/m$)

c) What is space charge of a p-n junction? Draw the I-V characteristics of a p-n junction and explain the nature of current flow under forward and reverse bias. 1+4

d) What is depletion layer photodiode? Discuss the key differences between photodiode and LED in terms of function, operating principle and biasing. 2+3

e) Explain briefly the quantization of lattice vibration. Discuss the inelastic scattering of photons by phonons and hence obtain the relation: 1+4

$$\Omega = \frac{2\,\upsilon\omega\mu\sin\varphi}{c}$$

(The symbols have usual meanings).

f) Obtain the expression of energy eigenvalues of electrons in presence of magnetic field. Explain the term Landau diamagnetism. 4+1

4. Answer the following questions (any four) 10 x 4 = 40

a) Discuss the Josephson effect? Find the expression for DC Josephson current. 4+6

b) What is London penetration depth? Derive the expression for London equations in superconductors and discuss their significance. 2+8

c) Find the expression for built in potential of a p-n junction and show that the depletion width is given by 2+8

$$W = \left[\frac{2\epsilon kT}{q^2}\left(ln\frac{N_a\,N_d}{n_i^2}\right)\left(\frac{1}{N_a}+\frac{1}{N_d}\right)\right]^{\frac{1}{2}}$$

(The symbols have their usual meanings)

d) What is Schottky contact? Discuss the rectifying and Ohmic metal-semiconductor contacts with proper band diagrams. Draw the equilibrium

band diagram and I-V characteristics of the $n - n^+$ junction. 1+6+3

e) i. Discuss the Beer's law for a material having absorption coefficient α and thickness l and hence deduce the relation 5

$$T = (1 - R)^2 exp(-\alpha l)$$

(The symbols have their usual meanings)

ii. Deduce the dispersion relation of a linear dielectric medium using Maxwell's equations in the absence of free charge and current densities. 5

f) i. What are excitons? Explain the effect of excitons on the absorption spectrum of semiconductors. 2+3

ii. Explain the term interband luminescence. Discuss the luminescence for direct band gap and indirect band gap semiconductors with the help of schematic band diagram 1+4

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