M.Sc. (Applied Physics) 4th Semester Examination, 2012

Material Physics - II

(PGP-401)

Full Marks : 100 **Time : 4 hours**

Use separate answer script for each group.

Answer FIVE questions, taking at least one from Sections I and II each of Group A and at least two from Group B.

GROUP A

Section-I

1. (a) Distinguish between the diamagnetic behaviors of Type-I and Type-II superconductors. Name a few materials belonging to each type.
   (b) Show how London's phenomenological theory accounts for the diamagnetic behavior of a Type-I superconductor.
   (c) A superconducting sphere of radius 1 cm is placed in a uniform magnetic field of strength 10^4 Gauss. Calculate the maximum value of the field on the surface of the sphere.
   (d) What is isotope effect? Point out its significance.
   For Hg, T_C =4.185 K for M= 199.5 amu. What would be the values of T_C for M=202.0 and 203.3 amu respectively? [4+6+6+4]

2. (a) Explain briefly how persistent bulk current in a superconductor can be understood qualitatively in terms of superconducting energy gap and correlated motion of Cooper pairs.
   (b) What is quenching of orbital angular momentum and where does it arise? Discuss briefly about its origin.
   (c) Write down Maxwell's relevant thermodynamic equations and explain how these may be employed to provide the theoretical framework for cooling by adiabatic demagnetization.
   (d) Explain why pre-cooling of the sample is necessary in the above method.
   (e) Calculate (i) the amount of heat rejected during isothermal magnetization and (ii) the final temperature achieved following adiabatic demagnetization of a sample of mass 2 g, initial temperature 2 K, Curie constant 0.042 CGS units/g, specific heat 0.1 Cal/g, under a magnetic field of 10 kGauss. [3+3+7+3+4]

Section-II

3. (a) A dielectric material is placed under the influence of an optical radiation. Considering the electronic contribution, show how resonant absorption occurs. Explain when we get anomalous dispersion.

   (b) Estimate the bulk polarization of a polar solid material assuming two stable molecular orientations, in the low frequency region. Explain why Clausius-Mossotti relation is not used here.

   (c) Draw the real part of the total polarizability vs. frequency.

   [(8+2) + (6+2) +2]

4. (a) What do you understand by Lyddane-Sachs-Teller (LST) relation? By which technique the parameters are experimentally measured?

   (b) Write short notes on: (i) Electrostriction and (ii) Phosphorescence

   (c) Assuming thermodynamical treatment, obtain the conditions of the parameters for the second-order ferroelectric phase transition. Hence distinguish the spontaneous polarization vs. temperature curves between the first and second order phase transitions.

   Calculate and plot the heat capacity of the ferroelectric material for a second order phase transition.

   [(2+1) + (2+3) + (6+2+4)]

GROUP- B

5. a) How can you differentiate between direct and indirect band gap materials? Give examples. Explain how radiative and non radiative recombination processes occur in those materials.

   b) Explain briefly the process of injection electroluminescence in LED. What are the basic criteria which have to be maintained during its construction?

   c) Explain how Lasing action becomes possible in case of a degenerately doped forward biased p-n junction. Also draw suitable diagrams.

   d) Draw a schematic illustration of a GaAs homojunction laser diode. How can you improve its performance by using heterostructure junction?

(2+1+2)+(3+3)+(3+2)+(2+2)

6. a) Describe in brief the performance of a photoconductor. Show that photocurrent gain for a photoconductor depends on the carrier life time and also the transit time between the electrodes.

   b) When a photodiode is used in photovoltaic mode, show that the output photo voltage is not linearly dependent on incident optical power.

   c) Explain why p-i-n photodiode is more suitable than a standard p-n photo diode. Draw suitable diagrams.

   d) Write short notes on

   (i) Avalanche photodiode, (ii) Various luminescence processes.

(2.5+2.5)+4+ (2.5+2.5)+(3+3)

7. a) What is numerical aperture of an optical fiber? By drawing suitable diagram show that for maximum acceptance angle $\mathbf{i_m}$ for a fiber with core index $\mathbf{n_1}$ and clad index $\mathbf{n_2}$

$$\sin i_m = \sin i = \sqrt{n_1^2 - n_2^2} \quad when\ n_1^2 < n_2^2 + 1$$
$$= 1 \quad when\ n_1^2 > n_2^2 + 1$$

   b) Obtain the following form of characteristic equation for a step index fiber.

$$\frac{uJ_l'(u)}{J_l(u)} = \frac{wK_l'(w)}{K_l(w)}.$$

   where $J_l(u)$ and $K_l(w)$ represents l-th order Bessel function and modified Bessel function respectively and u and w are given by

$$u = a\sqrt{k_0^2 n_1^2 - \beta^2} \text{ and } \qquad w = a\sqrt{\beta^2 - k_0^2 n_2^2}$$

   c) What is the importance of V parameter for analyzing the modal characteristics of an optical fiber? Draw the universal curves for normalized propagation constant b as a function of V parameter. From there explain cut-off of a mode in a fiber. Show that the LP_{01} mode has no cut-off.

(1+3)+10+(1+1+2+2)

8 a) Differentiate between macrobending and microbending loss in an optical fiber.

b) Explain in brief that how the information carrying capacity is affected by pulse dispersion in optical fibers. What is meant by pulse chirping ? Show how pulse form is changed due to dispersion induced chirping for fiber with normal and anomalous dispersion.

c) Show that the waveguide dispersion coefficient of a single mode optical fiber can be expressed as

$$D_w = -\frac{n_2 \Delta}{c\lambda} V \frac{d^2(Vb)}{dV^2}$$

where the symbols have their usual meanings.

d) Discuss the importance of dispersion compensation and dispersion slope compensation of optical fibers in a broad band optical communication system.

4+(2+2+2)+6+4