The Open University of Sri Lanka
Department of Electrical and Computer Engineering
ECX5243 – Physical and Opto Electronics
Final Examination – 2016/2017
Bachelor of Technology Honours in Engineering

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This paper has three sections. Answer **five questions which include at least one but not more than two questions from each section.** All questions carry equal marks. Adhere to the usual notations.

Note: *Charge of an electron* $= 1.602 \times 10^{-19}$ C, *Boltzmann constant* $= 8.617 \times 10^{-5}$ eV K^{-1}, *Planck's constant* $= 6.626 \times 10^{-34}$ Js and *the speed of light in a vacuum* $= 3 \times 10^{8}$ ms^{-1}. For any missing parameters suitable values can be assumed.

Section A

Q1.

(a) What is the meaning of the Fermi-Dirac probability function? [5]

(b) Determine the position of the Fermi level with respect to the intrinsic Fermi level in silicon at $T = 300$ K that is doped with phosphorous atoms at a concentration of 10^{15} cm^{-3}. [6]

(c) Repeat part (b) if the silicone is doped with boron atoms at a concentration of 10^{15} cm^{-3}. [4]

(d) Calculate the electron concentration in the silicon for parts (b) and (c). [5]

Q2.

(a) Derive equations for free electron/hole concentration of intrinsic semiconductors by stating all assumptions with reference to the energy band model of semiconductors. [5]

(b) The intrinsic carrier concentration n_i varies with temperature as $T^{3/2} \exp\left(-\frac{E_g}{2kT}\right)$ where k is Boltzmann constant. Calculate n_i for Ge at the following temperatures given that $n_i = 2.4 \times 10^{13} cm^{-3}$ at 300 K. Neglect any change of E_g with T and assume $E_g = 0.67$ eV.

i. −23 °C
ii. 127 °C
iii. 327 °C [12]

(c) Compare the values obtained in part (b). [3]

Q3.

(a) Explain what you mean by "Hall Effect" in your own words. [5]

(b) Germanium is doped with 5×10^{15} donor atoms per cm at 300 K. The dimensions of the Hall device are $d = 5 \times 10^{-3}$ cm, $w = 2 \times 10^{-2}$cm and $l = 10^{-1}$cm. The current is $I = 250\ \mu A$ the applied voltage is $V_x = 100$ mV and the magnetic flux density is $B_z = 5 \times 10^{-2}$ Tesla. Calculate

i. Hall voltage,

ii. Hall field and

iii. carrier mobility. [15]

Section B

Q4.

(a) What happens if the external voltage is suddenly reversed in a diode which has been carrying current in the forward direction? [10]

(b) How does depletion region capacitance of a reverse bias diode vary with the magnitude of the reverse voltage? [10]

Q5.

(a) Specify the condition when the base collector junction becomes forward biased and hence the transistor enters the saturation region. [10]

(b) Clarify the situation when the pinch-off condition occurs for smaller values of $|V_{DS}|$. What will happen to the maximum drain current? [10]

Section C

Q6.

(a) Justify the following statements with sufficient explanations:

i. Numerical aperture is a very useful measure of the light collecting ability of an optical fiber.

ii. Multimode graded index fibers exhibit far less intermodal dispersion than multimode step index fibers

iii. Intramodal or chromatic dispersion occurs in all types of fibers while intermodal dispersion occurs only in multimode fibers. [6]

(b) A step index fiber has a numerical aperture, NA = 0.2588 , core refractive index = 1.5 , cladding refractive index = 1.47 and a diameter 125μm. A light source is coupled to this fiber which emits 75% of its light into a 60 degree full-cone angle, 50% into a 30 degree cone and 25% into a 15 degree cone. Calculate the following when this source and fiber are connected:

(i) Acceptance angle

(ii) Coupling efficiency

(iii) The critical angle at the core cladding interface [9]

(c) If the above fiber is illuminated with IR light that has a vacuum wavelength of 2.50μm, determine:

(i) the V-number of the system.

(ii) the number of modes that can propagate in the fiber [5]

Q7.

(a) Briefly explain the 3 main processes involved in emission of radiation. [3]

(b) Lasers and LEDs are two main types of light sources used in optoelectronics. Explain the process of light emission occurred in each of these sources.

[6]

(c) Use the above answer in (b) to deduce that Lasers are monochromatic (single color wavelength), collimated (parallel rays) and coherent, in contrast, LEDs are neither coherent nor collimated and generate a broader band of wavelengths. [6]

(d) Explain why the use of direct band gap materials are more advantageous than indirect band gap materials in constructing semiconductor emitters. [5]

Q8.

(a) Using suitable diagrams explain the detection process of an intrinsic p-n photodiode. Compare this device with the p-i-n photodiode. [8]

(b) A Silicon p-n photodiode has a quantum efficiency of 65% when photons of energy 1.5×10^{-19} J are incident upon it.

Calculate,

(i) at what wavelength is the photodiode operating?

(ii) Responsivity of the detector

(iii) incident optical power required to obtain a photocurrent of 2.5μA when the photodiode is operating as described above.

[8]

(c) Briefly explain one application of optoelectronics in which it uses an optical detector as a parameter sensing device. [4]