The Open University of Sri Lanka
Department of Electrical and Computer Engineering
ECX5243 – Physical and Opto-Electronics
Final Examination – 2014/2015

Date: 2015-08-09 Time:0930-1230

This paper has three sections. Answer **five questions** by selecting **at least one question 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* $= 8.617 \times 10^{-5}$eVK^{-1}, *Speed of light* $= 2.998 \times 10^{8}$ms^{-1}. For any missing parameters suitable values can be assumed.

Section A

Q1.

(a) Explain the term "mobility" and discuss its dependence of temperature. [6]

(b)Silicon is doped with 4×10^{16} donor atoms per cm^3 at room temperature. A Hall device with dimensions of height 5×10^{-3} cm, width 3×10^{-2}cm and length 8×10^{-2}cm. The current and voltage applied are 250μA and 100 mV respectively. A magnetic field of 5×10^{-2} Tesla is applied. Calculate

(i) Hall Voltage [6]
(ii) Hall field and [4]
(iii) Carrier mobility [4]

Q2.

(a) With the use of an energy level diagram of an insulator explain why electrons in the insulator unable to conduct a current. [6]

(b) The bandgap energy in a semiconductor is usually a function of temperature and can be modeled as $E_g = E_g(0) - \frac{k_1 T^2 + k_2 T}{k_2 + T}$. For an unknown semiconductor material $E_g(0) = 1.310$ eV. The parameter values are given as $k_1 = 3.98 \times 10^{-4}$ eV/K and $k_2 = 541$ K.
Find the bandgap energy of the given material for $0 \leq T \leq 1000$ K in 200 K intervals. [10]

(c)Discuss the conduction property of the above unknown material. [4]

Q3.

(a)Why does a capacitance exist in a reverse biased p-n junction and it decrease with increasing reverse bias voltage? [6]

(b) Calculate the built in voltage V_0 at room temperature in a uniformly doped silicon $p-n$ junction with doping concentrations $N_A = 5 \times 10^{17}\text{cm}^{-3}$, $N_B = 2 \times 10^{17}\text{cm}^{-3}$ and $n_i^2 = 4 \times 10^{21}$. [7]

(c) Find the temperature which reduces the built in voltage by 2%. [7]

Section B

Q5.

(a) Discuss the assumptions which made for the derivation of the Ideal Diode Equation. [10]

(b) Compare the I-V characteristics of an Ideal Diode and a Real Diode. [10]

Q4.

(a) To switch a PNP transistor from cutoff to saturation, what should happen to the hole density in the base and how is this accomplished? [10]

(b) Explain why the collector current decreases when the transistor is operated in the saturation region. [10]

Section C

Q6.

(a) Briefly explain the following with suitable diagrams:

(i) acceptance angle
(ii) numerical aperture (NA)
(iii) total reflection [06]

(b) Briefly explain the difference between meridional rays and skew rays. [02]

(c) A multimode step index cylindrical fiber with a core diameter large enough to be considered by the Ray theory has a core refractive index of 1.5 and a cladding refractive index of 1.48. It has a core diameter of 80 μm and is operating at a wavelength of 0.85μm.

Determine,

(i) the critical angle at the core cladding interface
(ii) the NA for the fiber
(iii) the normalized frequency of the fiber
(iv) Total number of guided modes [08]

(d) Compare the acceptance angle of the above fiber for meridional rays with that for skew rays which change the direction by 100^0 at each reflection. [04]

Q7.

(a) Differentiate the following:

(i) Intrinsic absorption vs extrinsic absorption
(ii) Intramodal dispersion vs intermodal dispersion [04]

(b) Discuss the following statement:

"Intermodal dispersion in multimode fibers is minimized with the use of graded index fibers." [06]

(c) A 8 km optical link consists of multimode step index fiber with a core refractive index of 1.5 and a relative index difference of 1% . Estimate,

(i) the delay difference between the slowest and the fastest modes at the fiber output.
(ii) the rms pulse broadening per kilometer due to intermodal dispersion on the link.
(iii) the maximum bit rate that may be obtained without substantial errors on the link assuming only intermodal dispersion.

[10]

Q8.

(a) Briefly explain what stimulated emission is and how it relates to the operation of LASER. [08]

(b) State the main difference in the operating principles between LASER and LED. [03]

(c) Differentiate the operations of p-n diode and p-i-n diodes with the aid of suitable diagrams. [04]

(d) When 800 photons per second are incident on p-n-p photodiode operating at a wavelength of 1.3μm they generate on average 550 electrons per second which are collected. Calculate the quantum efficiency and the responsivity of the device. [05]