The Open University of Sri Lanka
Department of Electrical and Computer Engineering
ECX5243 – Physical and Opto-Electronics
Final Examination – 2015/2016

Date: 2015-12-06 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* $= 8.617 \times 10^{-5}\ eV\ K^{-1}$. For any missing parameters suitable values can be assumed.

Section A

Q1.

(a) Determine the probability of occupancy of a state that is located at $0.259eV$ above E_F at

i. $T = 0\ K$
ii. $T = 300\ K$
iii. $T = 600\ K$ [2X3]

(b) Determine the probability of vacancy of a state that is located at $0.4eV$ below E_F at $T = 300\ K$. [10]

(c) Repeat part (b) if the state is at $0.01\ eV$ above E_F at $T = 300K$. [4]

Q2.

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

(b) Germanium is doped with 5×10^{15} donor atoms per cm^3 at 300 K. The dimensions of the Hall device are $d = 5 \times 10^{-3}\ cm$, $w = 2 \times 10^{-2}\ cm$ and $l = 0.1\ cm$. The current $I = 250\ \mu A$, the applied voltage is $V_x = 100\ mV$ and the magnetic flux is $B_z = 5 \times 10^{-2}\ Tesla$. Calculate

i. The Hall voltage
ii. The Hall field and
iii. The carrier mobility [5X3]

Q3.

(a) Explain the meaning of the term "mobility" and its dependence on the frequency of collisions [6]

(b) Consider a uniformly doped silicon p-n junction with doping concentrations $N_A = 5 \times 10^{17}\ cm^{-3}$ and $N_D = 10^{17}\ cm^{-3}$.

i. Calculate the built in voltage V_0 at $T = 300\ K$ [8]
ii. Determine the temperature at which V_0 decreases by 1%. [6]

Section B

Q4.

(a) Briefly explain why the narrower the bang gap the higher is the intrinsic carrier density in a semiconductor. [10]

(b) Discuss why in an intrinsic semiconductor the Fermi energy level E_F does not lie exactly in the middle of the band gap. [10]

Q5.

(a) A student make a statement: "the electrons cross the junction from the n-type to the p-type and the holes cross the junction from p-type to the n-type". Discuss the validity of the statement. [10]

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

Section C

Select at least **one question** from this section.

Q6.

(a) Differentiate the following:

(i) Meridional rays and Skew rays

(ii) Single mode fiber and multimode fiber

(iii) Step index fiber and graded index fiber [2X3]

(b) Explain the important conditions for total internal reflection to exist in fiber. [2]

(c) Explain why only single mode fibers are used for high-speed optical communication systems. [2]

(d) A laser diode emits light at a wavelength 1.55μm. The light is coupled in an optical fiber. Calculate the wavelength, the frequency and the speed of the light in the optical fiber, which has a refractive index of 1.45. [4]

(e) (i) What do you mean by 'V number' of a optical fiber cable?

(ii) The number of modes in an optical fiber, having core and cladding refractive index of 1.48 and 1.46 respectively, is 14331. If the wavelength of light is 900nm, what is the core diameter? [6]

Q7.

(a) Explain how intermodal dispersion occurs in step index multimode optical fibre and show that how it is minimized by using graded index optical fibre. [6]

(b) Describe the how chromatic dispersion occurs in optical fiber explaining its main 2 types. [6]

(c) When a mean optical power is launched into an 8 km length of fiber is 12 μW, the mean optical power at the fiber output is 3 μW. Determine:

(i) Overall signal attenuation in dB.

(ii) The overall signal attenuation for a 10 km optical link using the same fiber with splices at 1 km intervals, each giving an attenuation of 1dB. [8]

Q8.

(a) Draw and explain the three key transition processes involved in laser action, illustrating your answer with appropriate diagrams. [3]

(b) "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." Justify the above statement with reasons. [7]

(c) (i) Define quantum efficiency and the responsivity of a photodetector.

(ii) Derive an expression for the responsivity of an intrinsic photodetector in terms of the quantum efficiency of the device and the wavelength of the incident radiation.

(iii) Photons having energy 1.5×10^{-19} Joules are incident on a photodiode having responsivity of 0.694 A/W.

a. At what wavelength is the photodiode operating?

b. Calculate the quantum efficiency of the photodiode.

c. If output power is 10 μW. Find the generated photocurrent.

d. Determine the wavelength at which the quantum efficiency and the responsivity are equal.

[10]