THE OPEN UNIVERSITY OF SRI LANKA
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

FINAL EXAMINATION - 2013/2014

ECX5239 – PHYSICAL ELECTRONICS **(Closed Book)**

This paper has two sections. Answer five questions selecting at least two questions from each section.

Adhere to the usual notations.

Date 27.08.2014 ***Time: 9:30-12:30 hrs.***

$$q_e = 1.602 \times 10^{-19} C$$
$$k = 1.38 \times 10^{-23} JK^{-1}$$

SECTION A

Q1.

(a) Clearly explain how an electron in a solid can have a continuous range of energy values inside a band, rather than occupying discrete levels as in an isolated atom. **(5Marks)**

(b) Draw the energy band diagram of Germanium and compare it to that of Diamond and to that of Copper. Clearly show the Fermi energy levels in your diagrams. **(6Marks)**

(c) Use the answer in (b) to explain the conductivity differences in Germanium, Diamond and Copper. **(3Marks)**

(d) Diamond is having a density of states in the conduction band $2 \times 10^{24} m^{-3}$ and has an energy gap of $5.6eV$. Calculate the conductivity of Diamond at room temperature.
$\mu_e = 4500\ cm^2V^{-1}s^{-1}, \mu_h = 3800\ cm^2V^{-1}s^{-1}$ **(6Marks)**

Q2.

(a) Considering the atomic bond structures, clearly and completely explain the conductivity variations in metals, semiconductors and insulators with the increased temperature. **(6Marks)**

(b) Diamond and Graphite are both Carbon allotropes. Use their atomic bond structures to explain the conductivity differences at room temperature. **(4Marks)**

(c) What will happen to the conductivity of Graphite once the temperature is increased? Reason your answer. **(4Marks)**

(d) A certain intrinsic semiconductor sample has a conductivity of $1.56 \times 10^{-3} \Omega^{-1} m^{-1}$ at $20^0 C$ and $4.9 \times 10^{-3} \Omega^{-1} m^{-1}$ at $30^0 C$. Let $\mu_e \propto T^{-\frac{3}{2}}$, $\mu_h \propto T^{-\frac{5}{2}}$ and also , $n_e, n_h \propto T^{\frac{5}{2}}$. Calculate the conductivity at $40^0 C$. **(6Marks)**

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Q3.

(a) Differentiate the intrinsic and extrinsic semiconductors. Compare their energy band diagrams highlighting the Fermi levels. **(4Marks)**

(b) Draw the energy band diagrams of n-type and p-type semiconductors. **(4Marks)**

(c) What is the benefit of compensation doping in semiconductors? **(4Marks)**

(d) A Si wafer is first doped uniformly with 10^{17} As atoms per cubic centimeter. Then it is compensation doped with 9×10^{16} B atoms per cubic centimeter. Calculate the final Fermi energy level with respect to that after doping with only As. $N_c = 1.1 \times 10^{25} m^{-3}$ **(8Marks)**

Q4.

(a) Clearly and completely explain the phenomenon of Hall Effect. **(6Marks)**

(b) Compare the Hall Effect in metals and in semiconductors. Explain how this difference occurs. **(4Marks)**

(c) Discuss the Hall Effect differences in n-type and p-type semiconductors. **(4Marks)**

(d)

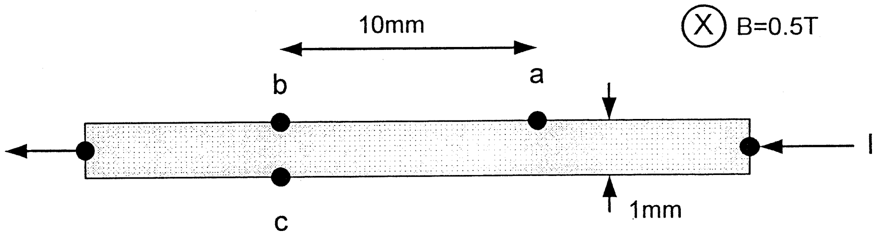

Fig-Q4

In the arrangement shown in Fig-Q4, a doped semiconductor has a square cross-section $1mm \times 1mm$. A constant current I flows along the length perpendicular to the cross-section. Further, $V_a - V_b = 100mV$ and $V_b - V_c = 0$ were measured before the application of the magnetic field B. Subsequently, after the application of the magnetic field of $B = 0.5T$ as shown (over the complete area of the setup, perpendicular to the paper), it was found that $V_b - V_c = 90\mu V$. What is the type of the semiconductor? Considering the equilibrium of forces on carriers, find the mobility of the carriers present. **(6Marks)**

SECTION B

Q5.

(a) Explain the operation of a p-n junction using the energy band diagrams. (You should consider all three bias conditions) **(6Marks)**

(b) What are the special construction considerations of a light emitting diode (LED)? **(4Marks)**

(c) What is the importance of a *direct band gap* semiconductor materials used in LEDs? **(4Marks)**

(d) With the help of appropriate graphs, state the effect of temperature variations and applied voltage variations to the output intensity of a forward biased LED. **(6Marks)**

Q6.

(a) List the special design features in a bipolar junction transistor (BJT). (You should state the doping concentrations and thickness of different sections in the BJT) **(3Marks)**

(b) Explain the operation of a pnp BJT at an atomic level highlighting how the amplification is achieved. **(7Marks)**

(c) What is the origin of the capacitive effects in the base-emitter junction? **(4Marks)**

(d) Clearly explain why the transit time across the base of the BJT controls the high-frequency current gain. **(6Marks)**

Q7.

(a) How does a MOSFET operate? Explain the atomic level behavior of an n-channel MOSFET. **(6Marks)**

(b) What is *saturation* in a MOSFET? Clearly show this region in a $I_D vs\ V_{DS}$ plot. **(6Marks)**

(c) With the help of the energy band diagrams for zero gate voltage and a negative gate voltage, explain the behavior of an n-channel JFET. **(8Marks)**

Q8.

(a) Do you believe the Sri Lankan contribution in the global semiconductor industry adequate? Discuss the potentials and limitations in this regards. **(8Marks)**

(b) What do you understand by *a hazard* in the semiconductor industry? **(2Marks)**

(c) Briefly explain the hazards which are associated with the local semiconductor industry. **(5Marks)**

(d) What measures can be taken to minimize these hazards? **(5Marks)**