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The Open University of Sri Lanka
Department of Electrical and Computer Engineering
ECX 5239 – Physical Electronics
Final Examination – 2011/2012

Date: 2012-03-14 Time: 1400-1700

Answer **five questions** by selecting **three from Section A** and **two from Section B.**

Note: $Charge\ of\ an\ electron = 1.602 \times 10^{-19}\ C$, $Mass\ of\ an\ electron = 9.109 \times 10^{-31}\ kg$

$Boltzmann\ constant = 8.617 \times 10^{-5}\ eV\ K^{-1}$.

For any missing parameters suitable values can be assumed.

Section A

Select **three** questions from this section.

Q1.

(i) Why the ability to conduct electricity or conductivity, higher in metals than in semi-conductors in room temperature?

(ii) The bandgap energy in a semiconductor is usually a slight function of temperature. In some cases the bandgap energy versus temperature can be modeled by

$$E_g = E_g(0) - \frac{\alpha T^2}{(\beta + T)}$$

where $E_g(0)$ is the value of the bandgap energy at $T = 0$ K. For silicon the parameter values are $E_g(0) = 1.170$ eV. $\alpha = 4.73 \times 10^{-4}$ eV/K and $\beta = 636$ K. Plot the variation of bandgap with temperature in suitable intervals over the range $0 \leq T \leq 600$ K. In particular, note the value at $T = 300$ K.

(iii) Interpret your results.

Q2.

(i) Briefly explain why the narrower the band gap, the higher is the intrinsic carrier density in a semiconductor.

(ii) Assume that silicon, germanium and gallium arsenide each have dopant concentrations of $N_d = 1 \times 10^{13}$ cm^{-3} and $N_a = 2.5 \times 10^{13}$ cm^{-3} at $T = 300$ K. For each of the three materials

(a) Is this material n type or p type?

(b) Calculate n_0 and p_0.

$Material$	n_i
Si	1.5×10^{10}cm^{-3}
Ge	2.4×10^{13}cm^{-3}
$GaAs$	1.8×10^{6}cm^{-3}

(iii) Interpret your results obtained in part (ii).

Q3.

(i) What is the meaning of the Fermi-Dirac probability function?

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

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

(c) Calculate the electron concentration in the silicon for parts (a) and (b).

Q4.

(i) Explain what you mean by "Hall Effect" in your own words.

(ii) Germanium is doped with 5×10^{15} donor atoms per cm^3 at $T = 300$ 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 $I = 250$ µA the applied voltage is $V_x = 100$ mV and the magnetic flux density is $B_z = 5 \times 10^{-2}$Tesla. Calculate

(a) the Hall voltage,

(b) the Hall field and

(c) the carrier mobility.

Q5.

(i) Why does a capacitance exist in a reverse-biased pn junction? Why does the capacitance decrease with increasing reverse bias voltage?

(ii) 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}.

(a) Calculate the built in voltage V_0, at $T = 300$ K.

(b) Determine the temperature at which V_0 decreases by 1 percent.

Section B

Select **two** questions from this section.

Q6.

(i) Discuss the assumptions which made for the derivation of the Ideal Diode Equation.
(ii) Compare the I-V characteristics of an Ideal Diode and a Real Diode.

Q7.

(i) Discuss about the photo-voltaic effect.
(iii) Explain the function of a Light Emitting Diode.

Q8.

(i) What are the advantages of simulating the I-V characteristics of a MESFET?
(ii) JFET Model for the GaAs MESFET I-V characteristics is given below. Discuss about the validity of the model.

$$V_{DS} < E_{VGS}V_{GS} - V_{TH}\ (linear\ region) : I_{DS} = \beta V_{DS}[2(E_{VGS}V_{GS} - V_{TH}) - V_{DS}](1 + \lambda V_{DS})$$

$$V_{DS} > E_{VGS}V_{GS} - V_{TH}\ (saturation\ region) : I_{DS} = \beta V_{DS}(E_{VGS}V_{GS} - V_{TH})^2(1 + \lambda V_{DS})$$