40

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The Open University of Sri Lanka

Department of Electrical and Computer Engineering

ECX 5239 – Physical Electronics

Final Examination – 2010/2011

Date: 2011-03-23 Time: 1400-1700

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

Note: $charge\ of\ an\ electron(e) = 1.602 \times 10^{-19}$ C , $Mass\ of\ an\ electron\ m_e = 9.109 \times 10^{-31}$ kg

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

Section A

Select **three** questions from this section.

Q1.

(i) What is *"energy band gap"* in solids? Discuss.

(ii) Draw the energy level diagram of an insulator and use it to explain why electrons in the insulator are unable to conduct a current.

(iii) The temperature dependence of the energy band gap E_g, has been experimentally determined yielding the following expression for E_g as a function of the temperature, T:

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

where $E_g(0)$, α and β are the fitting parameters. These fitting parameters are listed for germanium, silicon and gallium arsenide.

	Ge	Si	GaAs
$E_g(0)\ (eV)$	0.7437	1.166	1.519
$\alpha\ (meV/K)$	0.477	0.473	0.541
$\beta(K)$	235	636	204

(a) Calculate the energy band gap of germanium, silicon and gallium arsenide at 300 K, 400 K, 500 K and 600 K.

(b) Discuss the temperature dependency of energy band gap for these semiconductors.

(c) Discuss the conductivity of these semiconductors with reference to the energy band gap.

Q2.

(i) Explain the term "hall effect".

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

(iii) The Fermi energy level for a particular material at $T = 300$ K is 6.25 eV. The electrons in this material follow the Fermi-Dirac distribution function.

(a) Find the probability of an energy level at 6.50 eV being occupied by an electron.

(b) Repeat part (a) if the temperature is increased to T = 950 K.

(c) Calculate the temperature at which there is a 1% probability that a state 0.30 eV below the Fermi level will be empty of an electron.

Q3.

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

(ii) The intrinsic carrier concentration n_i varies with temperature as

$$T^{3/2} exp(-\frac{E_g}{2K_B T})$$

where $K_B = 8.62 \times 10^5$ eV/K. 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.

(a) −23°C (b) 127°C (c) 327°C

(iii) A value for the p-n junction reverse saturation current I_{sat} is found to be 1 μA at room temperature. Find the voltage that will produce a forward current of

(a) 1 mA (b) 1 A

Q4.

(i) Derive an equation for total drift current in a semiconductor by stating all assumptions.

(ii) Explain the relationship of temperature on total drift current.

(iii) Consider silicon at $T = 300$ K. Assume the electron mobility is $\mu_e = 1350$ cm^2/Vs. The kinetic energy of an electron in the conduction band is $\frac{1}{2} m_e^* v_d^2$ where m_e^* is the effective mass which can be taken as 1.08 times the mass of an electron and v_d is the drift velocity Determine the kinetic energy of an electron in the conduction hand if the applied electric field is

(a) 10 V/cm (b) 1 kV/cm.

Q5.

(i) Explain the meaning of the term "mobility" and its dependence on the frequency of collisions.

(ii) Derive an equation to the current density due to electrons.

(iii) A semiconductor material has electron and hole mobilities μ_e and μ_h respectively. When the conductivity is considered as a function of the hole concentration p,

(a) Show that the minimum value of conductivity σ_{min} can be written as

$$\sigma_{min} = \frac{2\sigma_i\sqrt{\mu_e\mu_h}}{(\mu_e+\mu_h)}$$ where, σ_i is the intrinsic conductivity and

(b) Show that the corresponding hole concentration is $p = n\sqrt{\frac{\mu_e}{\mu_h}}$.

Section B

Select **two** questions from this section.

Q6.

(i) What are the advantages of simulating the I-V characteristics of a MESFET?

(ii) Two models for the current voltage relationship in GaAs MESFET are given as follows.

JFET Model:

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

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

Hyperbolic Tangent Model:

$$I_{DS} = \beta(V_{GS} - V_{TH})Exp(1 + \lambda V_{DS})tanh(\alpha V_{DS})$$

Compare the I-V characteristics of the two models.

Q7. *"Characteristics of a practical Diode"*: Discuss with respect to

(i) Generation and recombination of carriers
(ii) Voltage drop across the neutral region
(iii) Breakdown

Q8. Write an essay on *"Occupational safety and health hazards in Sri Lankan semiconductor industry"*.