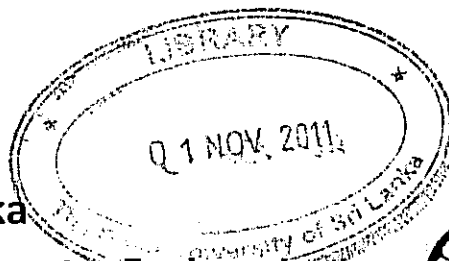


The Open University of Sri Lanka
 Department of Electrical and Computer Engineering
 ECX 5239 – Physical Electronics
 Final Examination – 2010/2011



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) = $1.602 \times 10^{-19} \text{ C}$, Mass of an electron $m_e = 9.109 \times 10^{-31} \text{ kg}$

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

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
$E_g(0) \text{ (eV)}$	0.7437	1.166	1.519
$\alpha \text{ (meV/K)}$	0.477	0.473	0.541
$\beta \text{ (K)}$	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

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

where $K_B = 8.62 \times 10^{-5}$ eV/K. Calculate n_i for Ge at the following temperatures given that $n_i = 2.4 \times 10^{13} \text{ cm}^{-3}$ 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 $1 \mu\text{A}$ 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 $\mu_e = 1350 \text{ cm}^2/\text{Vs}$. 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 band 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

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

(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:

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

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

Hyperbolic Tangent Model:

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

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".