Reg No.:_______________ Name:___________________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S3 (S,FE) (FT/WP) (S1 PT) Examination May 2025 (2019 Scheme)

Course Code: ECT201
Course Name: SOLID STATE DEVICES

Max. Marks: 100 Duration: 3 Hours

PART A

Answer all questions. Each question carries 3 marks Marks

1 Define Fermi- Dirac distribution function. Explain each term in it. Plot the function at temperatures T= 0 K, T_1 and T_2 ($T_1 > T_2$). (3)

2 Distinguish between intrinsic & extrinsic semiconductors. Draw the energy band diagram of an n -type semiconductor under thermal equilibrium. (3)

3 What are the scattering mechanisms present in a semiconductor? How do they affect the mobility of the carriers as temperature is varied? (3)

4 What are the components of conduction current in a semiconductor device? Write the equations of conduction current density. Plot the directions of hole & electron flux densities and current densities under thermal equilibrium. (3)

5 Plot the space charge and electric field distribution within the depletion region of a PN junction under equilibrium conditions. (3)

6 a) A contact is made between a metal and an n- type semiconductor with (i) $\Phi_m > \Phi_{sc}$ and (ii) $\Phi_m < \Phi_{sc}$. Draw the energy band diagrams under equilibrium and indicate the work functions, electron affinity and electron energy. (3)

7 What is meant by body effect in MOSFET? How does it affect the threshold voltage of the MOSFET? (3)

8 Plot the drain characteristics of an n- channel D-MOSFET. Give the drain current equations. (3)

9 Plot the subthreshold characteristics and explain subthreshold conduction in MOSFET. (3)

10 Explain the principle, structure and advantage of FinFET. (3)

PART B

Answer any one full question from each module. Each question carries 14 marks

Module 1

11 a) Derive the equation for the electron concentration in a semiconductor under thermal equilibrium. (8)

b) For a semiconductor under thermal equilibrium, effective densities of states in the conduction band and valence bands are given as $N_c = 10^{19} cm^{-3}$ and $N_v = 5x10^{18} cm^{-3}$, Energy band gap is 2 eV. Calculate the intrinsic carrier concentration at 900K. (6)

12 a) Plot the temperature dependence of carrier concentrations in extrinsic semiconductors and explain. (4)

b) With the help of suitable figures, explain direct & indirect recombination mechanisms. (4)

c) A sample of silicon is doped with $6x10^{13}$ cm^{-3} of Arsenic atoms and 10^{14} cm^{-3} of Boron atoms. (n_i= $1.5x10^{10} cm^{-3}$ for Silicon at 300 K) Find, (6)

i. the equilibrium electron and hole concentration at 300 K.

ii. the position of fermi level in the band gap.

Module 2

13 a) Derive Einstein's relation for electrons. (5)

b) Define Hall effect. (3)

c) A very long n-type semiconductor bar with cross sectional area = 0.5 cm^2 and $N_d = 10^{17} cm^{-3}$, is injected at one end with holes. The steady state excess hole concentration is $5x10^{16} cm^{-3}$ at x=0. Calculate the hole current at x= 1000 A°. (6)

(Hole mobility $\mu_p = 500\ cm^2/V$ Sec and hole lifetime $\tau_p = 10^{-10}$ Sec)

14 a) Derive the expression for diffusion current density in a semiconductor (7)

b) A Ge sample is doped with $2x10^{16} cm^{-3}$ Boron atoms and 10^{16} cm^{-3} Phosphorus atoms at 300 K. Find the current density, if an electric field of 3 V/cm is applied across the sample. (Mobility for electrons and holes are μ_n = 3800 cm^2/V Sec and μ_p = 1800 cm^2/V Sec respectively and intrinsic carrier concentration $n_i = 2x10^{13} cm^{-3}$ at 300 K) (7)

Module 3

15 a) Derive the ideal diode equation. (8)

b) What is base width modulation? How does it affect the output characteristics of a BJT? (6)

16 a) Derive the expression for minority carrier distribution and terminal currents in (8)

BJT .

b) A PN junction, doped on one side with 10^{18} cm^{-3} Boron atoms and the other side with 10^{16} $cm^{-3}$of Arsenic atoms at 300 K. ($n_i = 1.5x10^{10}cm^{-3}$ at 300 K and ϵ_r=11.9 for Silicon). Calculate, (6)

i. The built in potential

ii. Width of the depletion region

iii. Maximum electric field at the junction

Module 4

17 a) With the help of necessary band diagrams, explain equilibrium, accumulation, depletion and inversion modes of a MOS capacitor. (11)

b) An n channel MOS transistor is made on a P type silicon substrate with N_A= $5x10^{15}cm^{-3}$. The oxide thickness is 100 A°. (n_i = $1.5x10^{10}cm^{-3}$ at 300 K for silicon). Calculate the surface potential needed to make the surface i) Intrinsic ii) Strongly inverted. (3)

18 a) Derive the expression for drain current for an n-channel MOSFET. How the equation is modified in the linear and saturation regions of operations. (10)

b) An nMOS transistor has W/L= 4/2, gate oxide thickness 40 A°, Mobility of electrons 180 cm^2/Vsec. The threshold voltage is 0.4 V, relative permittivity of gate oxide ϵ_{ox}=3.9. Calculate the drain current when (4)

i) Vgs = 1.5 V, Vds = 1.8 V

ii) Vgs = 1.5 V, Vds = 0.3 V

Module 5

19 a) What is meant by scaling in MOSFETs? What is the motivation for scaling? (4)

b) Differentiate between the concept of constant voltage & constant field scaling. (6)

c) What is the impact of constant field scaling on the following parameters? (4)

i) Drain current ii) Delay iii) Device density and iv) Power density

20 a) What is a short channel MOSFET? (2)

b) Explain the following short channel effects and their influence the operation of a MOSFET. (12)

i) Channel length modulation ii) velocity saturation iii) DIBL

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