MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
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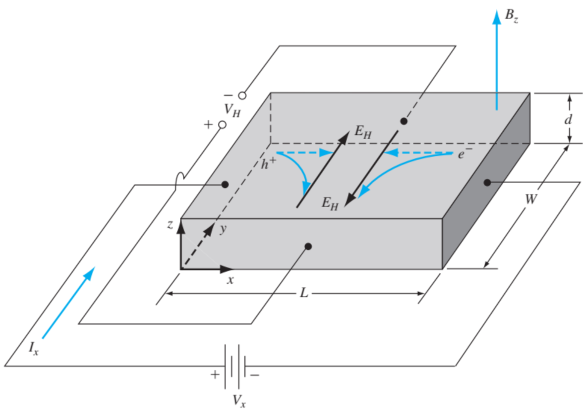
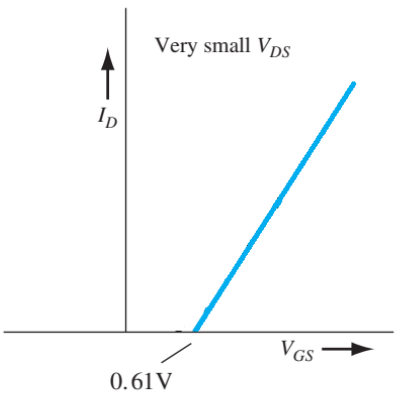
SIXTH SEMESTER BTECH. (E & C) DEGREE END SEMESTER EXAMINATION
MAY/JUNE 2024
SUBJECT: SEMICONDUCTOR DEVICE THEORY (ECE 4064), Regular

TIME: 3 HOURS **MAX. MARKS: 50**

Instructions to candidates
- Answer **ALL** questions.
- Missing data may be suitably assumed.

Q. No.	Questions	M	CO	CL
1A.	The probability that a state at $E_C + kT$ is occupied by an electron is equal to the probability that a state at E_V - kT is empty. Determine the position of the Fermi energy level as a function of E_C and E_V.	4	1	3
1B.	Determine the thermal-equilibrium electron and hole concentrations at T= 300 K. Assume $N_d = 5 \times 10^{15}$ cm^{-3} and $N_a = 0$. For (a) Silicon (b) GaAs and (c) Germanium.	3	2	3
1C.	Silicon at T = 300 K is doped with boron atoms such that the concentration of holes is $p_0 = 5 \times 10^{15}$ cm^{-3}. Determine (i) $E_F - E_V$. (ii) $E_C - E_F$. (iii) n_0. (iv) Which carrier is the majority carrier? (v) $E_{Fi} - E_F$.	3	1	3
2A.	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 $I_x = 250$ μA, the applied voltage is $V_x = 100$ mV, and the magnetic flux density is $B_z = 500$ gauss= 5×10^{-2} tesla. Calculate (i) the Hall voltage, (ii) the Hall field, and (iii) the carrier mobility.  	4	2	4
2B.	Consider a silicon p-n junction at zero bias and T=300 K, Assume doping concentrations of $N_a = 10^{16}$ cm^{-3} and $N_d = 10^{15}$ cm^{-3}. Determine (i) V_{bi}, (ii) x_n, (iii) x_p, (iv) W, (v) E_{max}, (vi) C_J.	3	3	3
2C.	A GaAs p-n junction at T=300 K has impurity doping concentrations of $N_a = 2 \times 10^{16}$cm^{-3} and $N_d = 5 \times 10^{15}$ cm^{-3}. It is determined that the ratio of junction capacitance	3	3	3

	at two reverse-biased voltages is Cj (V_{R1})/ Cj(V_{R2}) = 1.5, where V_{R1} 0.5 V. Determine V_{R2} and depletion width at V_{R2}.			
3A.	Gold is deposited on n-type silicon forming an ideal rectifying junction. The doping concentration is $N_d = 10^{16}$ cm^{-3}. Assume T=300 K. Determine the theoretical values of (i) ϕ_{B0}, (ii) V_{bi}, (iii) x_n and E_{max} at V_R=1 V.	4	4	3
3B.	Determine the theoretical barrier height, built-in potential barrier, and maximum electric field in a metal-semiconductor diode for zero applied bias. Consider a contact between tungsten and n-type silicon doped to $N_d=10^{16}$ cm^{-3} at T=300 K.	3	4	3
3C.	Discuss the metal-semiconductor junction with the appropriate band diagram, considering metal is deposited on n-type silicon and $\phi_M > \phi_S$.	3	4	2
4A.	Consider a GaAs n-channel p-n JFET at T=300 K with Na=10^{18} cm^{-3}, Nd=3×10^{15}cm^{-3}, and a=0.70 µm. Determine the forward-bias gate voltage required to open a channel region that is 0.10 µm thick with zero drain voltage.	4	4	3
4B.	The Schottky barrier height, ϕ_{Bn}, of a metal–n-GaAs MESFET is 0.90 V. The channel doping is $N_d=1.5\times10^{16}$ cm^{-3}, and the channel thickness is a=0.5 µm. T=300 K. (i) Calculate the internal pinch-off voltage V_{p0} and the threshold voltage V_T. (ii) Determine whether the MESFET is a depletion type or enhancement type.	3	4	4
4C.	An ideal MOS capacitor with an n polysilicon gate has a silicon dioxide thickness of t_{ox}=12 nm on a p-type silicon substrate doped at Na =10^{16} cm^{-3}. Given ϕ_{MS}=-1.10V. Determine the capacitance C_{ox}, C_{FB}, C_{min}, and C_{inv} at (a) f=1 Hz and (b) f=1 MHz.(c) Determine threshold voltage (d) Is the capacitor enhancement mode or depletion mode device.	3	5	3
5A.	Consider a MOS device with a p-type silicon substrate with Na=2×10^{16} cm^{-3}. The oxide thickness is t_{ox}=15 nm and the equivalent oxide charge is $Q_{ss}=7\times10^{10}$ cm^{-2}. Calculate the threshold voltage for (a) an n^+ polysilicon gate (ϕ_{MS}=-1.12V) (b) a p^+ polysilicon gate (ϕ_{MS}=+0.28V), and (c) an aluminium gate (ϕ_{MS}=-0.95V).	4	5	4
5B.	Calculate the aspect ratio W/L of the MOSFET and drain current of MOSFET at V_{GS}=1V. Consider the figure shown below for an n-channel silicon MOSFET at T=300 K, the straight line has a slope of 4×10^{-5}. Assume Cox = 6.9×10^{-8} F /cm^2, μ_n = 773 cm^2/V-s and V_D= 0.10V.  	3	5	4

5C.	Calculate the body-effect coefficient and the change in the threshold voltage due to an applied source-to-body voltage. Consider an n-channel silicon MOSFET at T=300 K. Assume the substrate is doped to $N_a=3\times10^{16}$ cm^{-3} and assume the oxide is silicon dioxide with a thickness of tox=20 nm. Let $V_{SB}=1$ V.	3	5	4