MODELLING OF VLSI DEVICE
(VLSI 5142)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Flat Band voltage is determined by
(a) Intrinsic Fermi level difference
(b) Quasi – Fermi level difference
(c) Electron affinity difference
(d) Metal – semiconductor work function difference, oxide and interface charge densities.

(ii) Velocity saturation of carriers in a short channel MOS device causes the drain current to saturate at
(a) Higher V_{DS} (b) V_{th}
(c) Lower V_{DS} (d) Same V_{DS}.

(iii) The MOSFET in its saturation region of operation behaves like a
(a) Constant current source (b) Diode
(c) Inductor (d) Capacitor.

(iv) In the forward active region of operation of the BJT,
(a) Emitter-base junction is forward biased, collector-base junction is reverse biased
(b) Emitter-base junction is forward biased, collector-base junction is forward biased
(c) Emitter-base junction is reverse biased, collector-base junction is reverse biased
(d) Emitter-base junction is reverse biased, collector-base junction is forward biased.

(vi) The charge density of a MOSFET in strong inversion varies with the surface potential
(a) linearly (b) exponentially
(c) parabolically (d) none of (a), (b) and (c).

(v) In degenerately doped *n* – type semiconductor the Fermi level lies in
(a) between the donor level and the conduction band
(b) conduction band
(c) below the donor level
(d) middle of the band gap.

(vii) The threshold voltage of a p-channel MOSFET under substrate bias
(a) increases (b) decreases
(c) remains unaltered (d) vanishes.

(viii) The channel output resistance of a MOSFET ideally is
(a) infinite (b) zero
(c) unity (d) none of (a), (b) and (c).

(ix) EKV drain current model describes the device operation for
(a) Weak inversion (b) Strong inversion
(c) Moderate inversion (d) all the three regions of inversion.

(x) HiSIM model is an example of
(a) SP model (b) CB model
(c) Vth model (d) none of (a), (b) and (c).

Group – B

2. (a) Draw the energy band diagrams of a pn junction under equilibrium, forward bias and reverse bias.

(b) Derive the expression for the total current density in a semiconductor when an electric field is applied in addition to carrier concentration gradients for both electrons and holes.

6 + 6 = 12

3. (a) Derive the necessary relation to prove that the Fermi level difference is the driving force for the flow of current in a semiconductor.

(b) Show the variation of the charge density with the surface potential in an NMOS. Obtain the expression for the threshold voltage of an ideal MOSFET.

6 + (3 + 3) = 12

Group – C

4. (a) Draw the energy band diagram of an NMOS under strong inversion. Calculate the value of the surface potential under strong inversion of an NMOS with $N_a=5\times10^{15}$/cc and $n_i=1.5\times10^{10}$/cc, respectively.

(b) Indicate the condition of strong inversion with the help of energy band diagram and derive the expression of threshold voltage.

(2 + 4) + (3 + 3) = 12

5. (a) Derive the drain current expression of a long channel n- MOSFET and explain the different regions of I – V characteristics.

   (b) Briefly discuss the substrate bias effect on the threshold voltage of the MOSFET.

8 + 4 = 12

Group – D

6. (a) What do you understand by short channel device and long channel MOSFET? Briefly discuss the short channel effects.

   (b) What do you understand by Ballistic transport?

(2 + 8) + 2 = 12

7. (a) Explain the techniques of constant field and constant voltage scaling of MOSFETs. Which method is preferred in industry and why?

   (b) What is GCA? Discuss the conditions for which this approximation is valid.

(6 + 2) + (2 + 2) = 12

Group – E

8. (a) Develop the SPICE LEVEL 1 MOSFET model from the expression of the drain current. Draw the equivalent circuit structure of LEVEL 1 MOSFET model.

   (b) Discuss the accuracy of LEVEL 1 MOSFET model.

(3 + 6) + 3 = 12

9. (a) Mention the characteristic features of BSIM 3 Model.

   (b) What are the properties of a good compact model?

6 + 6 = 12