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) In constant field scaling, the scaling factor is
(a) less than 1 (b) greater than 1
(c) equal to unity (d) greater than 0.5 .

(ii) 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).

(iii) The collector voltage at which the linearly extrapolated collector current of a BJT reaches zero is known as the
(a) early voltage (b) threshold voltage
(c) cut-off voltage (d) cut-in voltage.

(iv) The MOSFET in its linear region of operation behaves like a
(a) resistor (b) capacitor (c) inductor (d) diode.

(v) ITRS is the abbreviation of
(a) International Technology Roadmap for Semiconductors
(b) International Technology Roadmap for Semiconductor Devices
(c) Integrated Technology Roadmap for Semiconductors
(d) Integrated Technology Roadmap for Semiconductor Devices.

(vi) For logic circuits, the feature size of a MOS transistor refers its
(a) junction depth (b) gate length
(c) doping concentration (d) gate-oxide thickness.

(vii) The collector voltage at which the linearly extrapolated collector current of a BJT reaches zero is known as the
(a) early voltage (b) threshold voltage
(c) cut-in voltage (d) cut-off voltage.

(viii) BSIM3 is an example of
(a) Surface potential based model (b) Threshold voltage based model
(c) Charge based model (d) Transition width based model.

(ix) The Ebers-Moll model for a transistor describes it as two _____ in series.
(a) resistors (b) diodes (c) capacitors (d) inductors

(x) The minimum value of the body- effect coefficient of a MOSFET is
(a) zero (b) unity (c) ten (d) 100.

Group- B

2. (a) What are the mechanisms of carrier transport in a semiconductor? [(CO1)(Remember/LOCQ)]
(b) Write down appropriate expressions relating the conductivity due to each of these mechanisms. [(CO1)(Remember/LOCQ)]
(c) Show the variation of charge density with the surface potential in an NMOS. [(CO2)(Apply/IOCQ)]
2 + 4 + 6 = 12

3. (a) What is the built-in potential of a pn-junction? [(CO1)(Remember/LOCQ)]
(b) Explain why there is no net current flow through a pn-junction at equilibrium. [(CO1)(Understand/LOCQ)]
(c) Explain the dependence of the width of the depletion region of a pn-junction with applied bias and doping concentration. [(CO1)(Apply/IOCQ)]
4 + 2 + 6 = 12

Group - C

4. (a) Show with the help of an energy band diagram that the surface potential of a MOSFET under strong inversion is twice that of the Fermi potential. [(CO2)(Apply/IOCQ)]
(b) Define the threshold voltage of a MOSFET. Why is the channel called 'inverted'? [(CO2)(Remember/LOCQ)]
(c) Derive an expression to show the dependence of the threshold voltage of a MOSFET on the substrate bias. [(CO2)(Evaluate/HOCQ)]
5 + 2 + 5 = 12

5. (a) Draw the transfer characteristics of a MOSFET. [(CO2)(Remember/LOCQ)]
(b) Define the inverse subthreshold slope. What is its ideal value? [(CO2)(Apply/IOCQ)]
(c) Justify the need for having a low/high value of the subthreshold slope in VLSI circuits. [(CO2)(Analyze/IOCQ)]
3 + 5 + 4 = 12

Group - D

6. (a) Explain the dependence of threshold voltage on the length of a MOSFET. How can the threshold voltage roll-off in short channel MOSFETs be taken care of? [(CO4)(Analyze/IOCQ)]

(b) How are 'hot' electrons created in short channel devices? Discuss the vertical and lateral hot electron effects. [(CO4)(Understand/LOCQ)]

6 + 6 = 12

7. (a) What are short channel effects in MOSFETs? [(CO4)(Remember/LOCQ)]
   (b) Discuss the channel length modulation phenomenon in short channel MOSFETs. [(CO4)(Understand/LOCQ)]
   (c) How can ITRS be used in the development of models for advanced MOSFETs? [(CO5)(Apply/IOCQ)]

2 + 6 + 4 = 12

Group - E

8. (a) What are the properties of a good compact model? [(CO6)(Apply/IOCQ)]
   (b) Mention the characteristic features of BSIM 3 Model. [(CO6)(Remember/LOCQ)]

6 + 6 = 12

9. (a) How can compact models be classified? [(CO6)(Remember/LOCQ)]
   (b) What is GCA in MOSFETs? Discuss the conditions under which it is valid. [(CO6)(Apply/IOCQ)]
   (c) Discuss the accuracy of Level 1 MOSFET model. [(CO6)(Analyse/IOCQ)]

6 + 3 + 3 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	44.80	50	5.20

Course Outcome (CO):

After the completion of the course students will be able to

1. Students will learn BJT Modeling
2. Students will learn MOSFET Operation
3. Students will learn source of various MOSFET Capacitor Components
4. Students will learn SCE (Short Channel Effect) in MOS Devices
5. Students will learn MOS Scaling concepts on Future Technologies
6. Students will learn Industry Standard Compact Modeling

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.