MODELLING OF VLSI DEVICE
(VLI5142)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The Fermi level throughout a pn junction in thermal equilibrium is
(a) Constant (b) Different
(c) Broadened (d) Narrowed

(ii) The dominant current component in a MOSFET under strong inversion is
(a) drift (b) diffusion
(c) leakage current (d) drift and diffusion both

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

(iv) A MOSFET in saturation behaves like a
(a) constant current source (b) diode
(c)inductor (d) capacitor

(v) The gate length of MOSFETs of a 180 nm technology node is
(a) 90nm (b) 360 nm (c) 180 nm (d) 18 nm

(vi) Hot carrier effects in MOSFETs are mainly due to:
(a) Low channel resistance (b) High lateral electric field near the drain
(c) Gate leakage at zero bias (d) Low mobility carriers

(vii) Pao-Sah drain current model considers
(a) drift current transport mechanism
(b) diffusion current transport mechanism
(c) both drift and diffusion current transport mechanisms
(d) some assumptions for transport mechanism

(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) Presence of Substrate bias causes the subthreshold current in an nmos to
(a) increase (b) decrease
(c) remain unaltered (d) go to zero

(x) A charge-based compact model is particularly important for:
(a) Static I–V characteristics (b) Transient and RF analysis
(c) Doping profile extraction (d) Low-field mobility calculation

Fill in the blanks with the correct word

(xi) In constant voltage scaling, the voltages remain_____.

(xii) An example of a Vth- based compact model is _____.

(xiii) The voltage at which strong inversion occurs in a MOS capacitor is called the _____.

(xiv) In constant field scaling, both device dimensions and supply voltage are scaled down by a factor of _____.

(xv) A compact model that uses pre-calculated tabular data instead of analytical equations is called a _____ model

Group - B

2. (a) State the condition for equilibrium in a p-n junction and define built-in potential. *[(CO1) (Remember/LOCQ)]*

(b) Explain with a diagram how base-collector voltage affects collector current in a BJT. *[(CO1)(Understand/LOCQ)]*

(c) Derive the expression for collector current as a function of base-emitter voltage. *[(CO1)(Apply/IOCQ)]*

3 + 4 + 5 = 12

3. (a) Explain the dependence of the width of the depletion region of a pn-junction with applied bias and doping concentration. *[(CO1)(Apply/IOCQ)]*

(b) Using appropriate energy band diagrams show how the diffusion and drift current change in a pn-junction under forward and reverse bias. *[(CO1)(Apply/IOCQ)]*

6 + 6 = 12

Group - C

4. (a) Justify the nature of variation of the MOSFET capacitance with the applied gate voltage. Give suitable diagram. *[(CO3)(Evaluate/HOCQ)]*

(b) How does the substrate bias affect the threshold voltage of MOSFETs? *[(CO3)(Understand/LOCQ)]*

(5 + 3) + 4 = 12

5. (a) Using the relevant mathematical expression, determine how the drain current of a short channel MOSFET is dependent on the drain bias. *[(CO4)(Evaluate/HOCQ)]*

(b) Show the variation of the MOSFET capacitance with change of the gate-to-source voltage. *[(CO3)(Analyze/IOCQ)]*

(c) Define subthreshold swing of a MOSFET. Prove that the value of the subthreshold swing of a MOSFET cannot go below 60mV/decade. *[(CO4)(Evaluate/HOCQ)]*

5 + 2 + 5 = 12

Group - D

6. (a) What is 'scaling' of MOSFETs? Why is it necessary? *[(CO5)(Remember/LOCQ)]*
   (b) Compare full scaling and partial scaling. *[(CO5)(Analyze/IOCQ)]*
   (c) Justify the use of constant voltage scaling inspite of it being responsible for reliability issues of the MOSFETs. *[(CO5)(Evaluate/HOCQ)]*

2 + 4 + 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) Develop the SPICE LEVEL 1 MOSFET model from the expression of the drain current. *[(CO6)(Create/HOCQ)]*
   (b) Draw the equivalent circuit of LEVEL 1 MOSFET model. *[(CO6)(Apply/IOCQ)]*
   (c) Discuss the accuracy of LEVEL 1 MOSFET model. *[(CO6)(Analyse/IOCQ)]*

4 + 4 + 4 = 12

9. (a) List the different types of compact models used in MOSFET design. *[(CO6)(Remember/LOCQ)]*
   (b) Explain the difference between physical and empirical compact models with examples. *[(CO6)(Understand/LOCQ)]*
   (c) Analyze the limitations of threshold-voltage based models in modern VLSI technology. *[(CO6)(Analyze/IOCQ)]*

3 + 4 + 5 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	29.2	41.6	29.2