

**MODELLING OF VLSI DEVICE  
(VLSI 5142)**

**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 contact potential of a pn-junction is dependent on
  - (a) intrinsic carrier concentration
  - (b) doping concentration
  - (c) absolute temperature
  - (d) all of the above.
- (ii) The Fermi level throughout a pn junction in thermal equilibrium is
  - (a) Constant
  - (b) Different
  - (c) Broadened
  - (d) Narrowed.
- (iii) The dominant current in a MOSFET operating in the strong inversion region is due to
  - (a) drift
  - (b) diffusion
  - (c) both drift and diffusion
  - (d) leakage current of drain source pn-junctions.
- (iv) MOSFET uses the electric field of
  - (a) gate capacitance to control the channel current
  - (b) barrier potential of a pn-junction to control the channel current
  - (c) both (a) and (b)
  - (d) none of the above.
- (v) Flat band voltage is determined by
  - (a) intrinsic Fermi level difference
  - (b) quasi Fermi level difference
  - (c) electron affinity
  - (d) metal-semiconductor work function difference, oxide and interface charge densities.
- (vi) 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.

- (vii) Velocity saturation of carriers in a short channel MOSFET causes the drain current to saturate at  
 (a) the same  $V_{ds}$  (b) a lower  $V_{ds}$   
 (c) a higher  $V_{ds}$  (d) the threshold voltage.
- (viii) The channel output resistance of a MOSFET ideally is  
 (a) infinite (b) zero (c) unity (d) none of the above.
- (ix) A MOSFET in saturation behaves like a  
 (a) constant current source (b) diode  
 (c) inductor (d) capacitor.
- (x) 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.

*Fill in the blanks with the correct word*

- (xi) The depletion width of a pn junction widens under \_\_\_\_\_ bias condition.
- (xii) Channel length modulation is the dependence of the drain current on \_\_\_\_\_ in the saturation region of operation of the MOSFET.
- (xiii) In constant voltage scaling, the voltages remain\_\_\_\_\_.
- (xiv) Contact potential is the difference in potential developed across a pn junction at \_\_\_\_\_.
- (xv) BJT is a \_\_\_\_\_ controlled device.

### **Group - B**

2. (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](Understand/LOCQ)]  
**4 + 2 + 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. [[CO1](Evaluate/HOCQ)]  
 (b) Show the variation of the charge density with the surface potential in an nmos. [[CO3] (Apply/IOCQ)]  
 (c) Obtain the expression for the threshold voltage of an ideal MOSFET. [[CO2](Evaluate/HOCQ)]  
**6 + 3 + 3 = 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) Examine the dependence of the threshold voltage of a MOSFET on the substrate bias. [[CO2](Analyze/IOCQ)]
- 5 + 2 + 5 = 12**
5. (a) What is Gradual Channel Approximation? [[CO2](Remember/LOCQ)]
- (b) Write a short note on Pao-Sah's double integral. [[CO2](Understand/LOCQ)]
- (c) Write down the expressions for the drain current of an n-channel MOSFET in linear and saturation regions considering the channel length modulation phenomenon. [[CO2](Apply/IOCQ)]
- 2 + 4 + 6 = 12**

## Group - D

6. (a) Show the effect of full scaling on the following MOSFET parameters: intrinsic delay, power dissipation, power dissipation density, and the packing density. [[CO5](Apply/IOCQ)]
- (b) Write a short note on ITRS specifications. [[CO5](Remember/LOCQ)]
- 8 + 4 = 12**
7. (a) Explain the origin of the subthreshold current in a short channel MOSFET. [[CO4](Understand/LOCQ)]
- (b) What are 'hot' electrons? [[CO4](Understand/LOCQ)]
- (c) Show how the presence of hot electrons affect the operation of a short channel MOSFET. [[CO4](Analyze/IOCQ)]
- 5 + 2 + 5 = 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](Analyze/IOCQ)]
- 4 + 4 + 4 = 12**
9. (a) What are compact models? [[CO6](Remember/LOCQ)]
- (b) What are the properties of a good compact model? [[CO6](Understand/LOCQ)]
- (c) Compare the threshold voltage-based, charge-based and surface-potential based compact models for a MOS transistor. [[CO6](Analyze/IOCQ)]
- 2 + 4 + 6 = 12**

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	38.54	47.91	13.54

**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.*