

※ 考生請注意：本試題可使用計算機。請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

The following (1-7) are single-choice questions:

1. For a silicon NPN bipolar junction transistor with uniform emitter, base and collector doping, which of the following change causes the current gain  $\beta$  to increase (5pts)?
  - A. Higher base doping
  - B. Higher emitter doping
  - C. Larger base width
  - D. Larger collector width
2. Which of the following is the result of base width modulation for bipolar junction transistors in active mode (5pts)?
  - A. Lower current as  $V_{ce}$  increases
  - B. Lower output resistance
  - C. Lower transconductance  $g_m$
  - D. Higher input resistance
3. What is the purpose of the  $N^+$  sub-collector in NPN bipolar junction transistors (5pts)?
  - A. Increase current gain
  - B. Reduce emitter resistance
  - C. Reduce collector resistance
  - D. Reduce base resistance
4. What is the physical reason for  $\beta$  to decrease at very low current levels (as illustrated in Fig. 1) for bipolar junction transistors (5pts)?
  - A. High level injection
  - B. Kirk effect
  - C. Recombination in the emitter-base depletion region
  - D. Base width modulation
5. Which of the following did NOT happen during the scaling of silicon MOSFETs technologies from 1970s till today following Moore's law (5pts)?
  - A. Reduction of supply voltage  $V_{dd}$
  - B. Increase of gate oxide thickness
  - C. Reduction of source and drain junction depth
  - D. Reduction of gate length  $L$

6. Which of the following does NOT cause MOSFET output resistance  $r_o$  to decrease (5pts)?
- A. Drain induced barrier lowering
  - B. Substrate resistance
  - C. Channel length modulation
  - D. Self heating
7. Which of the following causes n-channel MOSFET threshold voltage  $V_{th}$  to DECREASE (5pts)?
- A. Larger body doping
  - B. Thicker gate oxide
  - C. Lower gate metal work function
  - D. Lower temperature
8. Explain the role (purpose) of lightly-doped drain (LDD) (also called the source and drain extensions) in a MOSFET (5pts).
9. List one way to suppress punch-through current in MOSFET (5pts).
10. Why DON'T we connect the body terminals to source terminals for all individual MOSFET transistors in an integrated circuit (IC) (5pts)?
11. (a) Explain briefly the reason why the effective mass of electrons in semiconductors is commonly less than the rest mass  $m_0$  or even negative. (6%)
- (b) Plot the current-voltage (I-V) curves of an n-type semiconductor and a forward-biased pn junction. Explain the physics underlying the difference in the I-V curves between these two devices. (6%)
- (c) Repeat part (b) for the case if the current  $I$  is increased to  $10I$ , what amount of bias should be increased for each device? (6%)
12. The energy band diagram of an ideal MOS structure at  $V_G = 0$  is shown in Fig. 2, where the body of the semiconductor is grounded. Please draw the energy band diagram when the gate is biased at threshold voltage and derive the voltage drop on the semiconductor. You are free to reasonably use any of the parameters required in your derivation. (16%)
13. (a) For the charge distributions shown in Fig. 3, which one or ones might occur in ideal semiconductor devices? Please briefly explain the reason behind your answer. (8%)
- (b) According to your answer, please derive the electric field and potential distributions. (8%)

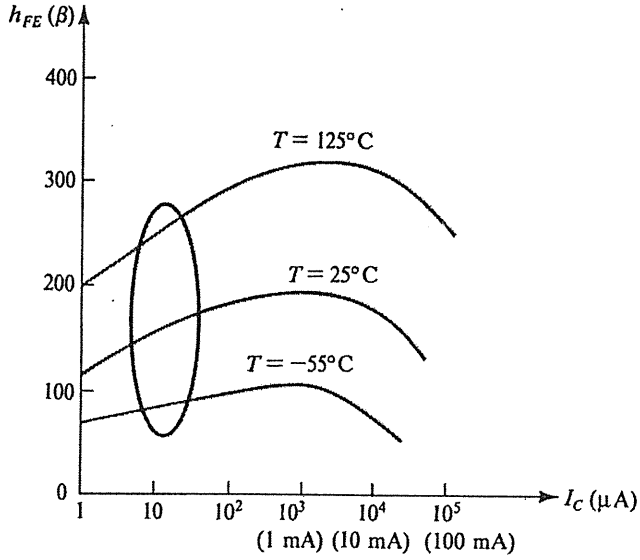


Fig. 1

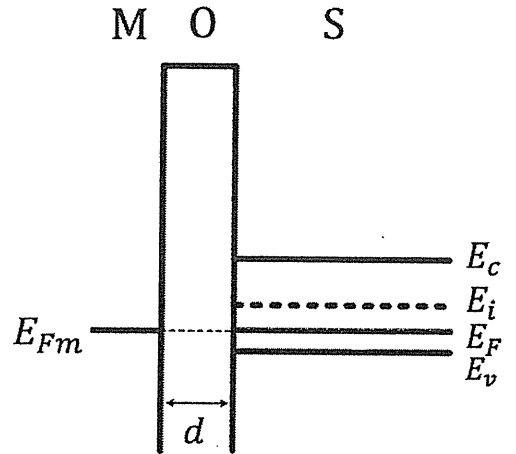


Fig. 2

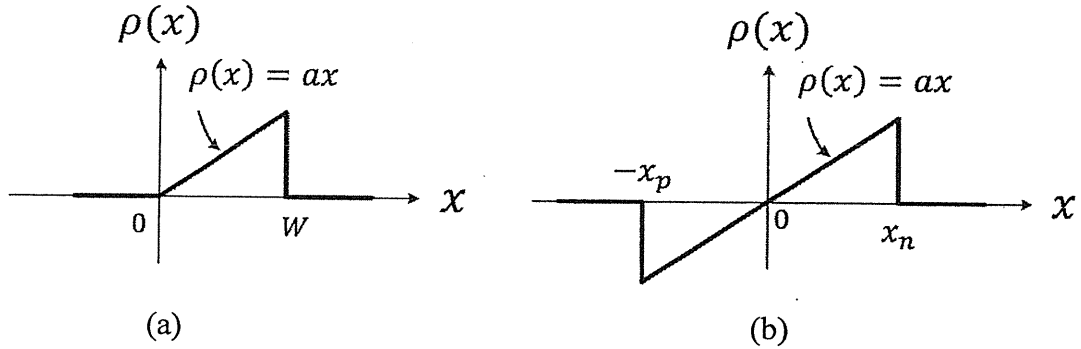


Fig. 3