Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**C**
Test:	**C1**
Type:	**Closed Book, Closed Notes**
Note:	**Available Info/Equation Sheets**

Problem Weighting--- **F-1...10 (1 each entry)**
F-2...18 (6 each part)
F-3...27 (a-3; b,c,d-7; e-3)
F-4...15 (1 ans–4 explain each part)
F-5...15 (3 each part)
F-6...15 (5 each part)

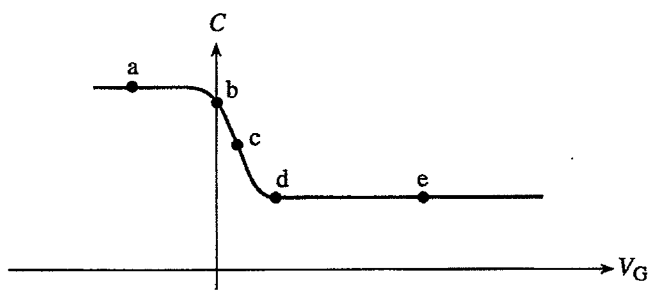
F – 1

[Outcome–(v)]

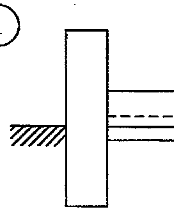
Score______/10

Complete the following table making use of the ideal-structure *C–V* characteristic and energy band diagrams in the figures below. For each of the biasing conditions named in the table, employ letters (a – e) to identify the corresponding bias point on the ideal MOS-C *C–V* characteristic. Likewise, use a number (1 – 5) to identify the band diagram associated with each of the biasing conditions.

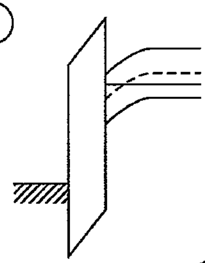
Bias Condition	*Capacitance (a–e)*	*Band Diagram (1–5)*
Inversion		
Depletion		
Flat band		
$V_G = V_T$		
Accumulation		



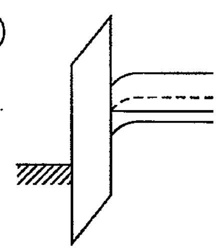
(1)



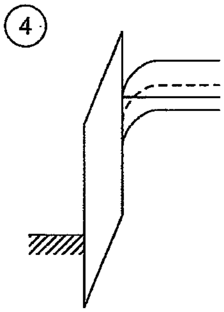
(2)



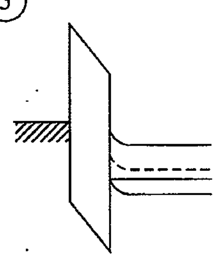
(3)



(4)



(5)

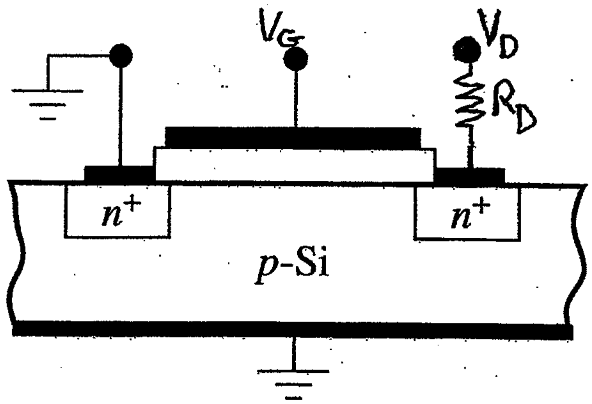


F – 2

[Outcome–(v)]

Score______/18

Suppose a resistor, R_D, is connected between the *n*-channel MOSFET drain terminal and the drain contact as pictured below.



(a) Appropriately modifying the square-law derivation, obtain an expression for I_D below pinch-off as a function of V_G, V_D and the voltage drop across the R_D resistor. Do NOT attempt to solve for I_D as a function of V_D and V_G.

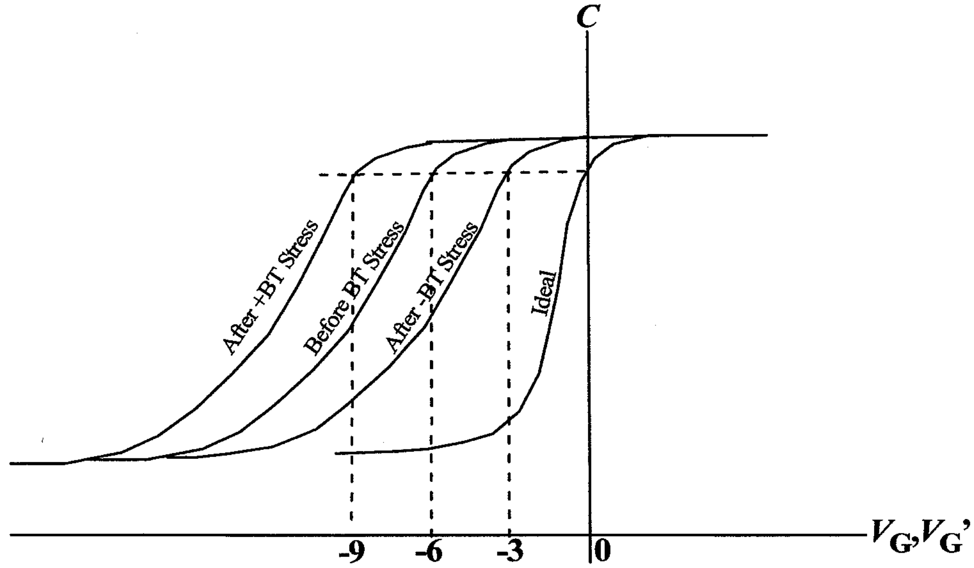
(b) Establish an expression for V_{Dsat}.

(c) Establish an expression for I_{Dsat} in terms of $V_G - V_T$.

F – 3

[Outcome–(v)] Score______ /27

An Al-SiO_2-Si MOS-C subjected to Bias-Temperature (BT) stressing yields the after +BT stressing and after –BT stressing C–V_G characteristics pictured below. Also shown on the same plot is the characteristic observed before any BT stressing and the ideal C–V_G' characteristic. The maximum observed capacitance is 100pF, the Si doping is $N_D = 10^{15}/\text{cm}^3$, and the gate area $A_G = 10^{-2}\text{cm}^2$.



(a) Q_{IT} is nonzero, where Q_{IT} is the interface trap charge. How does one come to this conclusion by inspecting the given characteristics?

(b) Q_M = ?, where Q_M is the total mobile ion charge in the oxide.

(c) Recalling $\Phi_M' - \chi' = -0.03$ eV in an Al-SiO2-Si structure, what is the metal-semiconductor workfunction difference (φ_{MS}) in the given MOS-C?

(d) Under the assumption that $Q_{IT} = 0$ under flat band biasing, determine Q_F. Q_F is the fixed charge at the oxide-semiconductor interface.

(e) Indicate the physical cause of the oxide charges listed below. (Possible causes include Phosphorus ions, Sodium ions, Nitrogen ions, Dangling bonds at the Si surface, Trapped electrons, Ionized Si waiting to be oxidized, Ionized oxygen waiting to form SiO2, and Trapped holes.)

Q_{IT}...physical cause is –

Q_M...physical cause is –

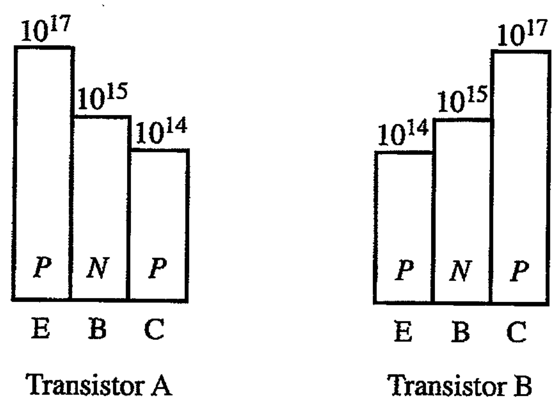
Q_F...physical cause is –

F – 4

[Outcome–(vi)]

Score______/15

Two *pnp* BJTs are identical except that the emitter and collector region dopings are interchanged as illustrated in the figure below.



(a) Which transistor is expected to have the greater emitter efficiency? **Explain.**

(b) Which transistor will exhibit the greater sensitivity to base width modulation under active mode biasing? **Explain.**

(c) If limited by avalanche breakdown of the C-B junction, which transistor will exhibit the larger V_{CB0}? **Explain.**

F – 5

[Outcome–(vi)] Score______/15

The electron and hole currents inside a *pnp* BJT biased in the active mode are plotted in the figure below. All the currents are referenced to I_I, the hole current injected into the base.

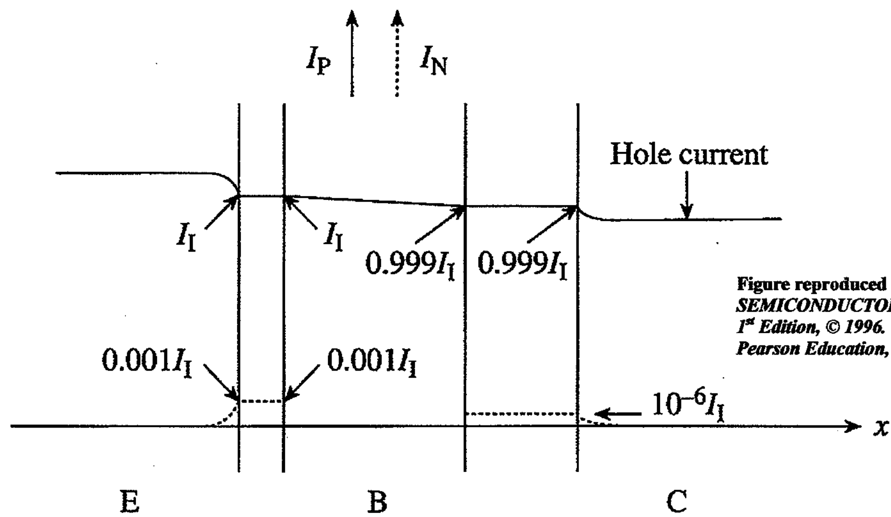


Figure reproduced from *PIERRET, ROBERT F., SEMICONDUCTOR DEVICE FUNDAMENTALS, 1st Edition, © 1996. Reprinted by permission of Pearson Education, Inc., Upper Saddle River, NJ.*

Determine:

(a) The emitter efficiency (γ):

(b) The base transport factor (α_T);

(c) The common emitter d.c. current gain (β_{dc});

(d) The base current (I_B);

(e) For the given transistor, is the recombination-generation current arising from the depletion regions negligible as assumed in the ideal transistor analysis? **Explain.**

F – 6

[Outcome–(vi)] Score______/15

(a) Draw the large signal equivalent circuit for a *pnp* BJT based on the Ebers-Moll equations.

(b) Draw the typical shape of the common emitter output characteristics derived from a *pnp* BJT. Note the variables plotted on the *x* and *y* axes. (No numerical values are required.)

(c) Draw the typical shape of a Gummel plot. Note the variables plotted on the *x* and *y* axes.