Course:	**Semiconductor Device Fundamentals**
Level:	**Undergraduate**
Module:	**C**
Test:	**C3**
Type:	**Closed Book, Closed Notes**
Note:	**Available Info/Equation Sheets**

Problem Weighting--- **F-1...30 (a,c,e–2; b-4; d,f,g,h-5)**
F-2...30 (a-16, b-7 each part)
F-3...20 (4 each part)
F-4...20 (a,c-2; b,d,f-3; e-7)

F – 1

[Outcome–(vi)] Score_____/30

An IDEAL metal-SiO_2-Si capacitor (MOS-C) with a doping parameter $\phi_F/(kT/q) = 15$ is maintained at $T = 300$K and biased such that $\phi_S/(kT/q) = 10$.

[2] (a) Is the semiconductor n-type or p-type? Explain how you arrived at your answer.

[4] (b) Determine the semiconductor doping (N_A or N_D).

[2] (c) The MOS-C is depletion biased. How does one arrive at this conclusion?

[5] (d) Draw the MOS-C block charge diagram corresponding to the applied bias. For reference purposes note W_T on your diagram. Also, specifically note the physical origin of the (+) and (–) charges on your diagram.

[2] (e) What is the POLARITY of the gate voltage (V_G)? Explain how you arrived at your answer.

(Continued)

[5] (f) Draw the MOS-C energy band diagram corresponding to the applied bias. (Be sure to include the diagrams for all three components of the MOS-C, show the proper band bending in both the oxide and semiconductor, and properly position the Fermi level in the metal and semiconductor.)

[5] (g) Determine the hole concentration (p) in the semiconductor next to the Si-SiO_2 interface under the specified biasing condition.

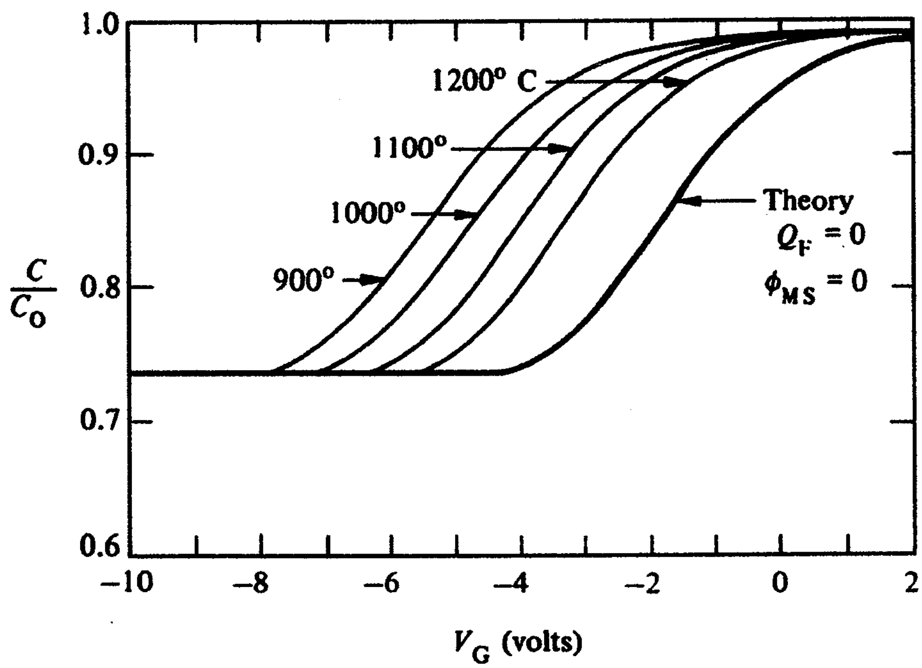
[5] (h) Sketch and LABEL the high-frequency, low-frequency, and deep-depletion C–V characteristics to be expected from the given ideal MOS-C. Also, label the flat band point (FB) and the depletion-inversion transition voltage (V_T) on your sketch.

F – 2

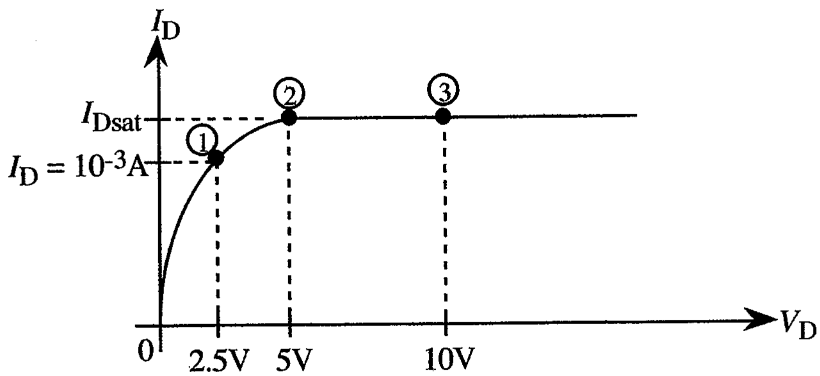
[Outcome–(vi)] Score_____ /30

[16] (a) ECE text Fig. 18.9(a) is reproduced below. The figure illustrates the effect of the oxidation temperature on the fixed charge in metal-SiO_2-Si structures. The *C–V* data was derived from an Al-gate MOS-C with an $x_o = 0.2\mu m$ and $N_D = 1.4 \times 10^{16}/cm^3$. $\Phi_M' - \chi' = -0.03eV$ for an Al-gate MOS-C.

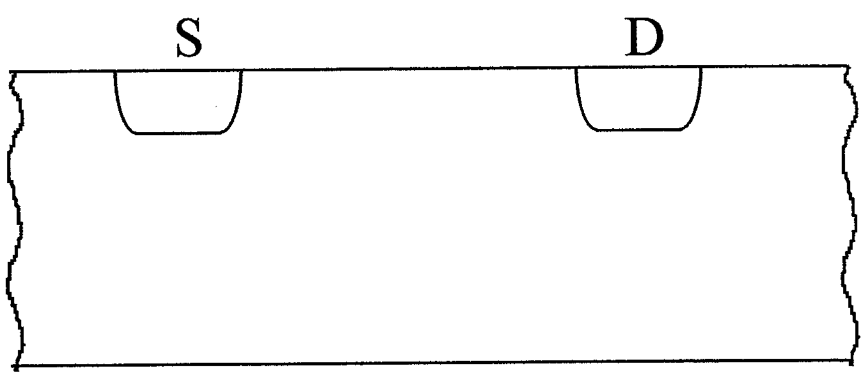
As accurately as possible, determine the number of fixed charges/cm^2 (Q_F/q) associated with the oxidation at **1100°C**. Assume $Q_M = 0$ and $Q_{IT} = 0$. Record all work.



(b) An I_D–V_D characteristic derived from an ideal MOSFET is pictured below. Note that $I_D = 10^{-3}$A when $V_D = 2.5$V. Answer the questions that follow making use of the square-law theory and the information conveyed in the figure.



[7] (b-i) Complete the figure below, carefully sketching the inversion layer and the depletion region inside the MOSFET corresponding to point (3) on the pictured characteristic. Also insert the doping type of the source and drain islands and the semiconductor bulk.

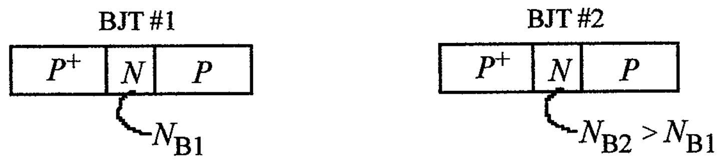


[7] (b-ii) Determine the value of I_{Dsat} for the given characteristic.

F – 3

[Outcome–(vii)] Score____/20

Two silicon *pnp* BJTs maintained at 300K are identical except the doping concentration in the base (N_B) is greater in BJT #2. $W_B << L_B$ in both BJTs. Compare the operation of the two BJTs by answering the questions that follow. Assume identical biasing of the two BJTs in working parts (a) through (c).



NOTE: *No explanation → No credit.* You may use equations in your explanations.

[4] (a) Which BJT will exhibit the larger emitter efficiency (γ)?
1) BJT #1 2) BJT #2 3) Same for both (Circle one)
EXPLANATION:

[4] (b) Which BJT will exhibit the larger base transport factor (α_T)?
1) BJT #1 2) BJT #2 3) Same for both (Circle one)
EXPLANATION:

[4] (c) Which BJT will exhibit the larger common base d.c. current gain (α_{dc})?
1) BJT #1 2) BJT #2 3) Same for both (Circle one)
EXPLANATION:

[4] (d) Assuming punch through limits the observed V_{CB0}, which BJT will exhibit the large V_{CB0}?

1) BJT #1 2) BJT #2 3) Same for both (Circle one)

EXPLANATION:

[4] (e) Assuming avalanche breakdown of the CB junction limits the observed V_{CB0}, which BJT will exhibit the large V_{CB0}?

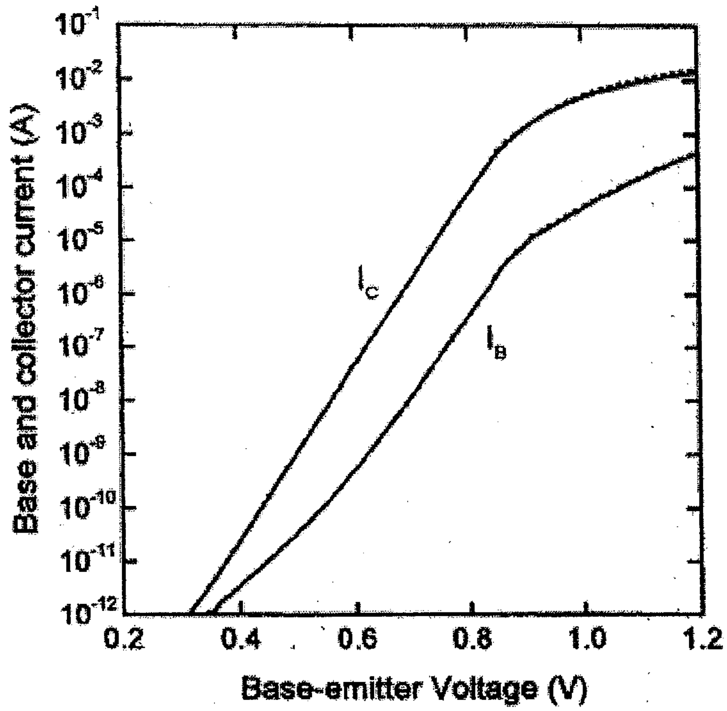
1) BJT #1 2) BJT #2 3) Same for both (Circle one)

EXPLANATION:

F – 4

[Outcome–(vii)] Score____ /20

Answer the questions that follow referring to the experimental BJT data reproduced below. The I_C and I_B vs. V_{BE} curves (with $V_{CB} = 1V$) were derived from a BJT maintained at room temperature.



[2] (a) What is the name of the pictured plot?

[3] (b) Was the data derived from a *pnp* or an *npn* transistor? Explain how you arrived at your answer.

[2] (c) What is the physical cause of the increased slope of the I_B curve below approximately $V_{BE} = 0.6V$?

[3] (d) What are the possible physical causes of the "slope-over" in the I_C curve at current levels in excess of $I_C \cong 10^{-3}$A?

[7] (e) Assuming the linear portion of the I_C curve obeys the relationship $I_C = I_{C0}\exp(qV_{BE}/nkT)$ determine "n" (as best as you can) from the given data.

[3] (f) Determine the common emitter d.c. current gain (β_{dc}) of the BJT when $I_C = 10^{-6}$A and $V_{CB} = 1$V. Record all work.