ECSE-2210 MET – Final Exam – Fall Semester 2016

1. A pnp Si bipolar junction transistor (BJT) has an emitter doping of $N_{A,\ Emitter} = 1 \times 10^{19}\ cm^{-3}$ and base doping of $N_{D,\ Base} = 1 \times 10^{17}\ cm^{-3}$. The emitter efficiency of the BJT is $\gamma = 0.999$.
   (a) Calculate the base width, W_B, of the BJT. You may make use of the electron diffusion length formula $L_n = (D_n\ \tau_n)^{1/2}$ where τ_n is the minority carrier lifetime.
   (b) Calculate the BJT's current amplification in the common emitter configuration, β.
   (c) In practical BJTs, the current amplifications (α and β) slightly increase when V_{CE} is increased. Why do α and β slightly increase when V_{CE} is increased? Explain.

2. Consider an ideal MOS capacitor (with $\Phi_{metal} = \Phi_{semi}$ and $Q_{oxide} = 0$) consisting of a metal (M), an oxide (O), and an n-type semiconductor (n-type Si).
   (a) Assume that the MOS capacitor is under equilibrium conditions. Sketch the band diagram. Label everything you sketch appropriately.
   (b) Assume that the MOS capacitor is under strong inversion conditions. Sketch the band diagram. Label everything you sketch appropriately.
   (c) Sketch the charge-density-versus-spatial-coordinate diagram ($\rho(x)$-versus-x diagram) including all charges of the MOS capacitor under strong inversion conditions. Sketch the electrostatic-potential-versus-spatial-coordinate diagram (Φ-versus-x diagram) of the MOS capacitor under strong inversion conditions.

3. Consider a GaAs MESFET (Metal-semiconductor FET) with an electron concentration of $n = 10^{16}\ cm^{-3}$. Assume that the MESFET has a gate length of $L_G = 1.0\ \mu m$, a gate width of $Z = 250\ \mu m$, and a channel width of $W_{channel} = 0.75\ \mu m$. Assume that the barrier height of the metal-semiconductor barrier is $e\,\Phi_{Barrier} = 1.0\ eV$.
   (a) Draw the band diagram of the FET at the gate location under equilibrium conditions and label everything appropriately.
   (b) Calculate the pinch off voltage of the MESFET.
   (c) Calculate the transconductance of the FET (g_m) at a gate voltage of $V_{GS} = 0\ V$. Name one application where an FET is preferable over a BJT (bipolar junction transistor); justify your answer.

4. Determine if the following statements are true or false. Explain your answers with a few words.
   (a) Positively charged sodium ions (Na^+) located in the gate oxide of an p-inversion-channel MOSFET will increase the FET's threshold voltage (i.e. increase $|V_{th}|$).
   (b) If the gate length (L_G) and width (Z) of a Si MOSFET are reduced by 50%, then the amplification (transconductance g_m) of the FET will remain approximately unchanged and the area occupied by the FET decreases to about 25% of its original value.
   (c) pnp Si BJTs (bipolar junction transistors) generally have a higher current amplification than npn Si BJTs because the base of pnp BJTs is n-type, and $\mu_n > \mu_p$.

Feel free to look up the physical constants and the material parameters (e.g. GaAs material parameters) that you need to solve the above problems. Show your work! Always give units! Please write your name on first page.