Problem 1: Consider the emitter follower in Fig. 7, which is being used as an output stage. For $Q_1$, assume $\beta = \infty$ and initially assume that $V_{BE} = 0.7$ V.

(a) For $A = 3$, plot $v_{out}$ and $I_E$ in the space provided in Fig. 2. [4]
(b) What is the efficiency of this output stage? [3]
(c) Assuming $I_S = 10^{-14}$ A, calculate the exact values of $V_{BE}$ at the minimum and maximum values of $V_{out}$. [4]
(d) What output stage performance characteristic is affected by the change in $V_{BE}$? [1]
(e) What is the maximum allowable value of $A$ to maintain class A operation? [2]

Figure 1: Emitter follower.
Problem 1 (cont’d)

Figure 2: Plots for emitter follower.
Problem 2: Consider the inverter shown in Fig. 3, where $V_{DD} = 5$ V. For both transistors, $\mu C_{ox} \frac{W}{L} = 200 \times 10^{-6}$ A/V^2, $V_A = \infty$, and $V_{tn} = |V_{tp}| = 1$ V. [10 points]

(a) What are the high and low output levels ($V_{OH}$ and $V_{OL}$) for this inverter? (hint: when $V_{in} = V_{DD}$, the pmos is in the saturation region and the nmos is in the triode region) [6]

(b) What is the static power consumption of this inverter, assuming it is driven by a 50% duty-cycle square wave with levels of 0 and $V_{DD}$? [4]
Problem 3: Consider the common source amplifier shown in Fig. 4. Assume the transistor has been biased in the saturation region (biasing circuitry not shown) with $I_D = 1$ mA. Additionally, $\mu_n C_{ox} \frac{W}{L} = 617 \times 10^{-6}$ A/V^2, $V_A = \infty$, and $C_{gs} = 1$ pF (you may ignore all other parasitic capacitors). [16 points]

(a) What is the low frequency gain ($V_{out}/V_{in}$) for this amplifier? [4]
(b) Find the frequency dependant transfer function ($V_{out}(s)/V_{in}(s)$) for the amplifier. [6]
(c) Draw the bode plot for the amplifier in the space provided in Fig. 5. [6]

Figure 4: Common source amplifier.
Figure 5: Bode plot.
Problem 4: Consider the feedback configuration depicted in Fig. 6. [8 points]

(a) What is the closed-loop gain of this feedback configuration? [5]

(b) What is the pole location of the closed-loop system when $A_1 = 10$, $A_2 = \frac{10}{1+s/\omega_p}$, $\beta_1 = 1$, and $\beta_2 = 1$? [3]
**Problem 5:** Borat has asked us to design a verrr nice laptop computer for him, and we need a gate to implement the logic function \( Y = \left( (\overline{A} + (\overline{B} \cdot \overline{C})) \cdot \overline{D} \right) \). [16 points]

(a) Provide a CMOS implementation for this logic gate. [6]

(b) Assuming that the nmos devices have twice the mobility of the pmos devices, size the transistors for equal worst-case drive strengths in the pull-up and pull-down networks. [6]

(c) If the maximum propagation delay in the logic of our system is 0.5 ns, what is the highest clock speed that we can design for? [1]

(d) The complete system has 2 million gates, each driving an average load capacitance of 5 fF, and the probability of each gate switching on a given clock cycle is 0.5. For a total power consumption of 15 mW, what clock speed should we choose for the system? [3]
Problem 6: A bistable multivibrator is shown in Fig. 7, where the opamp has power supplies of ±5 V and the diode is ideal with a turn-on voltage of 1 V (the diode becomes a short circuit with a 1 V drop when it is forward biased by 1 V). [12 points]

(a) Draw the voltage transfer characteristics for this circuit on the plot provided in Fig. 8. You may neglect the current in the 1 MΩ resistor when the diode is on, its only purpose is to pull $V_+$ to ground when the diode is off. [10]

(b) If the $V_{in}$ source is removed and a low-pass $R$-$C$ circuit is used to connect $V_{out}$ to $V_{in}$, will this circuit oscillate? Why or why not? [2]
Figure 8: Plot for VTC of bistable multivibrator.
Problem 7: How will Prof. Charles spend his time during the upcoming holiday break? [2 points]

(a) Writing research grants, so that he can get tenure in 2012.
(b) Skiing, since he doesn’t stand a chance of getting tenure in any case.
(c) Reminiscing about the good times in ECE 3110.
(d) Building a giant snow man on the roof of MEB.
(e) Other: ____________________________