ES154

Problem Set #5
(Due Thursday, November 14)

1. (S&S 4.64) The transistor in the circuit shown in Figure 1 is biased to operate in the active mode. Assuming that \( V \) is very large, find the collector bias current \( I_C \). Replace the transistor with the small-signal equivalent circuit model of Fig 4.27(b) [T model with a current controlled current source] (remember to replace the dc power supply with a short circuit). Analyze the resulting amplifier equivalent circuit to show that

\[
\frac{v_{01}}{v_i} = \frac{R_E}{R_E + r_E} \quad \frac{v_{02}}{v_i} = \frac{-\alpha R_C}{R_E + r_E}
\]

Find the values of these voltage gains (\( \alpha = 1 \)).

2. (S&S 4.78) For the common emitter amplifier shown in Figure 2, let \( V_{CC} = 9 \) V, \( R_1 = 27 \) k\( \Omega \), \( R_E = 1.2 \) k\( \Omega \), and \( R_C = 2.2 \) k\( \Omega \). The transistor has \( \beta = 100 \) and \( V_A = 100 \) V. Calculate the DC bias current \( I_E \). If the amplifier operates between a source for which \( R_S = 10 \) k\( \Omega \) and a load of 2 k\( \Omega \), replace the transistor with its hybrid-\( \pi \) model, and find the values of \( R_i \), the voltage gain \( v_0/v_i \), and the current gain \( i_0/i_i \).

3. (S&S 4.79) Using the same topology as in number 2, design an amplifier to operate between a 10 k\( \Omega \) source and a 2 k\( \Omega \) load with a voltage gain of –8. The power supply available is 9 V. Use an emitter current of about 2 mA and a current of about one tenth that in the voltage divider that feeds the base, with the dc voltage at the base about one third of the supply. The transistor available has \( \beta = 100 \) and \( V_A = 100 \) V.

4. (S&S 4.85) The BJT in the circuit of figure 4 has \( b = 100 \).
   (a) Find the dc collector current and the dc voltage at the collector.
   (b) Replacing the transistor by its T model, draw the small signal equivalent circuit of the amplifier. Analyze the resulting circuit to determine the voltage gain.

5. (S&S 5.5) An n-channel MOS device in a technology for which oxide thickness is 2 nm, minimum gate length is 1 \( \mu \)m, and \( V_t = 0.8 \) V, operates in the triode region, with small \( v_{ds} \) and with the gate-source voltage in the range 0 V to +5 V. What device width is needed to ensure that the minimum available resistance is 1 k\( \Omega \)?
6. (S&S 5.6) Consider an n-channel MOSFET with $t_{ox} = 20$ nm, $V_t = 0.8$ V, and $W/L = 10$. Find the drain current in the following cases:
   a. $vgs = 5$ V, $vds = 1$ V
   b. $vgs = 2$ V, $vds = 1.2$ V
   c. $vgs = 5$ V, $vds = 0.2$ V
   d. $vgs = vds = 5$ V

7. (S&S 5.42) For the circuits in Figure 7, find the drain voltages, assuming $k_n'(W/L) = 200 \mu A/V^2$, $V_t = 2$ V, and $V_A = 20$ V.