Instructions, notes, and hints:

Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

Some problems might be solvable (or must be solved) using good engineering approximations or assumptions. In those cases, your answer might differ from the posted answer by a fairly large margin. Given typical device variations and component tolerances, that amount of discrepancy is often reasonable. If you justify any approximations you make, you will be given full credit for such answers.

Assignment:

Problem 9.52 (omit gain-bandwidth product part) in the textbook plus the following additional problems:

1. Use the dominant pole concept to estimate the upper and lower band limits of the midband range for the common-gate amplifier circuit shown below. Before finding the numerical values of the pole frequencies, first find symbolic expressions for the pole frequencies in terms of the resistances and capacitances in the circuit. The MOSFET has parameter values $k_n = 4 \text{ mA/V}^2$, $V_t = 1 \text{ V}$, $C_{gs} = 8 \text{ pF}$, $C_{gd} = 0.5 \text{ pF}$, and $C_{ds}$ is negligibly small. Identify which single capacitors have the most dominant effect in determining the upper and lower limits of the midband region.
2. This problem illustrates some of the interesting characteristics of amplifier circuits with significant inductances present. Consider the following RF amplifier circuit, which is designed to amplify signals at or close to a frequency of 7 MHz. You may assume that capacitors $C_i$ and $C_o$ act as shorts (why?) and that the internal capacitances of the BJT act as opens at the operating frequency. The ambient temperature is approximately 290 K. The source voltage applied to the input is given by

$$v_{\text{sig}}(t) = 10 \cos(2\pi \times 7 \times 10^6 t) \text{ mV}.$$  

![RF Amplifier Circuit Diagram]

**a.** Find the bias levels of the collector voltage ($V_C$) and the collector current ($I_C$).

**b.** Plot the total collector voltage as a function of time [$v_c(t)$] at the operating frequency of 7 MHz. You may assume that $\beta \approx 120$. *Hint:* Solve the problem in the frequency domain (i.e., using reactances and phasors) first, convert the result to the time domain, and then add the time-domain result to the quiescent voltage. There are a few valid approximations that can simplify the analysis.

**c.** Find the peak collector voltage. How does it compare to $V_{CC}$? How can this situation be possible?

3. Estimate the lower and upper cut-off frequencies $f_L$ and $f_H$ and the mid-band gain $A_M$ for an amplifier whose voltage transfer characteristic is described by the expression given below. *(Hint: The midband gain is not $4 \times 10^{-4}$.)* Manipulate the expression so that it can be rewritten into a form in which the various pole frequencies and the midband gain are obvious; that is, the gain can be read directly from the expression and the low and high-frequency poles can be immediately identified. You may plot the expression to help you identify the midband region, but the values of $f_L, f_H$, and $A_M$ must be found analytically.

$$A_r(j\omega) = 4 \times 10^{-4} \frac{(j\omega)^2}{(1 + j\frac{\omega}{40})(1 + j\frac{\omega}{5000})(1 + j\frac{\omega}{600000})}$$

(continued on next page)
4. The circuit shown below is the basis for the ELEC 351 Lab #10 exercise. The quiescent collector current is 500 $\mu$A. From the 2N3904 data sheet, the unity-gain frequency $f_T$ is 300 MHz for a collector current of 10 mA. Assuming that the collector-to-base capacitance $C_C$ remains unchanged at 1 pF with respect to the quiescent current, find the upper cut-off frequency $f_H$ of the midband region. Next, suppose that the quiescent collector current is roughly doubled to 1 mA by changing the resistor values to $R_1 = 65$ k$\Omega$, $R_2 = 20$ k$\Omega$, and $R_E = 2$ k$\Omega$. Find the new upper frequency limit $f_H$. You may assume that $V_{BE} = 0.7$ V, $\eta = 1$, $V_T = 25$ mV, and $\beta = 150$. For full credit, you must show the derivation of the relevant equivalent resistance formulas. Compare the $f_H$ values you obtain at the two quiescent current levels and briefly discuss some of the implications of the results.

5. Explain in your own words why the Miller effect does not exacerbate the limitation of the upper cut-off frequency in the emitter follower circuit in the previous problem. In other words, it should be clear that the internal capacitance $C_C$ bridges the input and output signal nodes in the circuit. Why then is the upper cut-off frequency nevertheless relatively high?