Problem #1

An operational amplifier is used to make a feedback amplifier as shown above. Its open-loop Bode gain plot is also sketched with straight lines. It has two poles at $10^5$ and $10^7$ rad/s, respectively.

1. Using the same straight line, sketch the frequency response $v_o/v_i$ on the above plot, and mark the low-frequency gain and the cut-off frequency.

\[ f = \frac{10^5}{10^5 + 9 \times 10^6} = \frac{10}{10}, \quad \text{Gain} = 10, \quad \text{f_BW} = \frac{10^7}{10} = 10^6 \text{rad/s} \]

2. Is the phase margin greater than 60°? Explain why.

\[ \text{PM} = 90° - \tan^{-1} \left( \frac{10^6}{10^7} \right) = 90° - \tan^{-1} \left( \frac{1}{10} \right) > 60° \]

3. If $v_i(t) = \sin(10^6t)$ in steady state, what is $v_o(t)$?

\[ v_o(t) \approx 0.71 \sin \left( 10^6t - \frac{\pi}{8} \right) \]

4. If the low-frequency output resistance of the opamp is 1kΩ, what is the low-frequency output resistance of this amplifier?

\[ R_o \approx \frac{1k\Omega}{10^4} = 0.1k\Omega \]
Problem #2

An emitter degenerated bipolar amplifier is shown with the input bias voltage \( V_i \). The input and output small signals are marked as the low-case \( v_i \) and \( v_o \), respectively. Use the followings: \( kT/q = 25\text{mV} \), \( V_{\text{BE}} = 0.7\text{V} \), \( V_{\text{CESat}} = 0.2\text{V} \).

1. What is the maximum bias voltage \( V_i \) to keep the transistor in the forward-active range of operation?

\[
\begin{align*}
5 - 10 (v_i - 0.7) - 0.2 &= V_c - 0.7 \\
11v_i &= 12.5, \quad v_i \approx 1.1\text{V}
\end{align*}
\]

2. What is the DC bias voltage \( V_i \) to set the output DC voltage to be 3V?

\[
\begin{align*}
\frac{v_c - 0.7}{1k} &= 0.2\text{mA} \quad v_c = 0.9\text{V}
\end{align*}
\]

3. Estimate the low-frequency small-signal voltage gain \( v_o/v_i \) in the above bias condition.

\[
A_v \approx -\frac{R_c}{R_E} = -10
\]

4. What is the -3dB bandwidth?

\[
BW = \frac{1}{2\pi \times 10k \times 1\text{pF}} \approx 16\text{MHz}
\]