Consider the two-stage amplifier in Fig. 1. The circuit parameters, at $T = 25^\circ C$, are the following:

$V_{CC} = 15 \, V$, $R_g = 10 \, k\Omega$, $R_B = 1.8 \, M\Omega$, $R_C = 10 \, k\Omega$, $R_E = 1.2 \, k\Omega$, $R_D = 6.8 \, k\Omega$, $R_S = 1 \, k\Omega$, $R_L = 100 \, k\Omega$, $R_F = 2.2 \, k\Omega$, $C_B = 10 \, nF$, $C_L = 1 \, \mu F$, $C_F = 1 \, \mu F$.

$Q_1$: $V_{BE} = -0.7 \, V$; $\beta_F = 100$; $\beta_0 = 100$; $r_0 = +\infty$;

$Q_2$: $V_T = 2 \, V$; $I_{DSS} = k_n \frac{W}{L} V_T^2 = 0.2 \, mA$; $r_0 = +\infty$;

$V_T = 25 \, mV$.

Considering all capacitors to be equivalent to open circuits, determine:

1. the operating points $(V_{CE}, I_C)$ of $Q_1$ and $(V_{DS}, I_D)$ of $Q_2$.

Assuming all capacitors to be equivalent to short circuits at the frequencies of interest, determine also:

2. the voltage gain $A_v = v_o/v_g$ of the amplifier;
3. the output resistance indicated in the figure;
4. the low frequency bandwidth limit of the amplifier.
Exercise 2

Consider the operational amplifier configuration shown in Fig. 2. The circuit parameters are the following:

\[ R_1 = 18 \, \text{k}\Omega; \, R_2 = 56 \, \text{k}\Omega. \]

\[ A(s) = \frac{A_0}{(1 + \frac{s}{\omega_{p1}})(1 + \frac{s}{\omega_{p2}})} \, [\text{V/V}], \text{ with } A_0 = 10^5 \, [\text{V/V}]; \, \omega_{p1} = 10^2 \, \text{rad/s}; \, \omega_{p2} = 5 \cdot 10^5 \, \text{rad/s}. \]

Determine:

1. an estimation of the circuit *phase* margin with \( R_C = +\infty; \)
2. a block diagram representation of the amplifier;
3. the expression of the closed loop gain of the compensated amplifier, assuming \(|T| > 1|; \)
4. the values of \( R_C \) and \( C_C \) that yield a +45° phase margin (hint: place the crossover frequency of loop gain \( T \) exactly a decade lower than \( \omega_{p2} \), and place the compensation network zero *at the same frequency*).