This exam consists of 4 problems, each counting 25% of the total score. You must show your work in deriving values, even when your answers are correct. The amount of partial credit for incorrect answers will be based on the level of understanding you demonstrate in explanations and derivations.

1. For the circuit shown below estimate the high frequency point at which \( A_{Vs} \) becomes 0.707 of its maximum value. For this problem you need to determine the Q point and verify operation in the constant current (forward active) region.

\[
\beta_0 = 100 \\
C_n = 5.7 \, \text{pF} \\
C_\mu = 1 \, \text{pF}
\]

\[
\begin{align*}
\beta_0 &= 100 \\
C_n &= 5.7 \, \text{pF} \\
C_\mu &= 1 \, \text{pF}
\end{align*}
\]

2. For the circuit shown below estimate the low frequency point at which \( A_{Vs} \) becomes 0.707 of its maximum value. The drain current for this problem is 1mA, \( V_{GS} = -1.36 \, \text{V} \) and \( V_{GD} < V_T \), so operation is in the constant current (current saturation) region.

\[
K = 2.5 \, \text{mA/V}^2 \\
V_T = -2 \, \text{V}
\]

\[
\begin{align*}
K &= 2.5 \, \text{mA/V}^2 \\
V_T &= -2 \, \text{V}
\end{align*}
\]
3. Using **only pnp BJT devices** (along with resistors and capacitors as needed) design a coupled-emitter differential amplifier (that uses current source biasing) that has a differential mode gain \(v_o/v_{in}\) of 10, CMRR greater than 60 dB, and differential mode input impedance greater than \(1k\Omega\). The current source should deliver a total of 1mA of current, the collector emitter voltage (bias) should be about -5V, the source impedance is \(50\Omega\) and the load impedance is \(10k\Omega\). Assume a supply voltage of +15V. Sketch the circuit configuration and specify all resistor values being used. Assume transistor parameters of \(V_A=100V\), and \(\beta=100\).

4. Draw the high frequency small-signal model for the amplifier shown below. (Assume it is biased so that both devices are in the forward active region.) Be sure to carefully label all components and to indicate input and output voltages and currents. (The small signal models for Q1 and Q2 must include \(C_\pi\), \(C_\mu\), \(r_\pi\), \(r_o\) and the voltage dependent current source.)
Effect of emitter bypass capacitor:

\[ f_1 = \frac{1}{2\pi R_E C_E} \quad \text{and} \quad f_2 = \frac{1}{2\pi R'_E C_E} \]

where \( R'_E = R_E \parallel \left( \frac{r_\pi + R_B \parallel R_S}{\beta + 1} \right) \)

(continued next page)

Formula sheet (continued)
Current source design equations

Simple current source  \( I_{ref} = \frac{V_{CC} + V_{EE} - V_f}{R_1} \)

Widlar current source  \( I_o = \frac{V_T}{R_2} \ln \left( \frac{V_{CC} + V_{EE} - V_f}{R_1 I_o} \right) \)

Wilson current source  \( I_o = \frac{V_{CC} + V_{EE} - 2V_f}{R_1} \)

Current source output impedances:

Simple current source  \( R_o = r_o \)

Widlar current source  \( R_o = r_o(1 + g_m R_2) \)

Wilson current source  \( R_o = \left( 1 + \frac{B}{2} \right) r_o \)