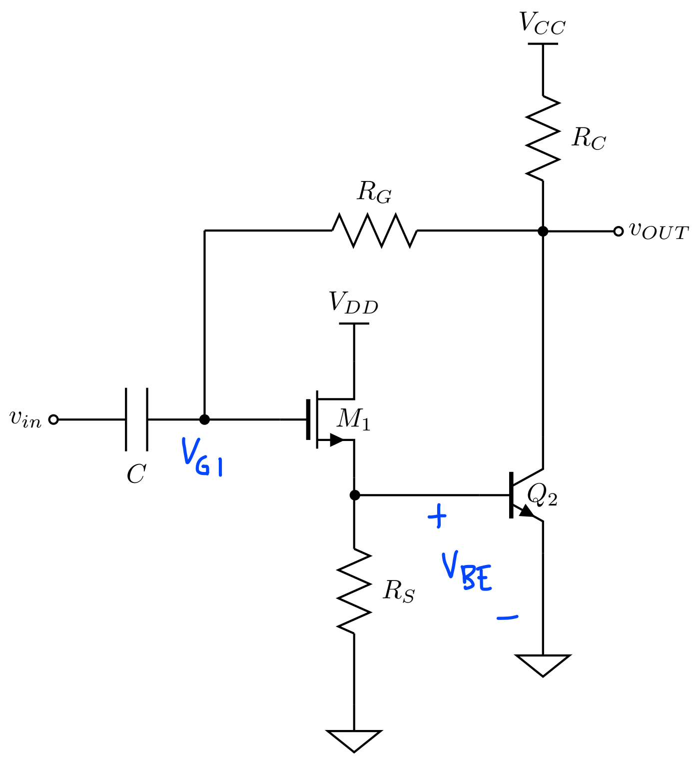
Part I:

(20 points) In the BiCMOS amplifier circuit below, $V_{DD} = V_{CC} = 5\,V$, $R_G = 10\,\mathrm{M}\Omega$, and $C \to \infty$. The BJT has $V_{BE} = 0.7\,V$, $V_{CE,SAT} = 0.2\,V$, $V_A \to \infty$, and $\beta \to \infty$ while the NMOS has $V_{TH} = 1\,\mathrm{V}$, $k = 2\,\frac{\mathrm{mA}}{\mathrm{V}^2}$, and $\lambda \to 0$.



1. Given $R_G = 10\,\mathrm{M}\Omega$, $R_S = 6.8\,\mathrm{k}\Omega$, and $R_C = 3\,\mathrm{k}\Omega$, determine the quiescent currents and voltages for both transistors. *(8 points)*

since $V_{BE} = 0.7\,V$, $I_{D1} = \dfrac{0.7}{R_S} = 102.94\ \mu A$

$V_{DS1} = V_{DD} - 0.7 = 4.3V$

$V_{GS1} = V_{TH} + \sqrt{\dfrac{I_{D1}}{k}} = 1.23\,V$

since $I_G = 0$; $V_{OUT} = V_{GS1} + 0.7 = 1.93V$

$I_{C2} = \dfrac{V_{CC} - V_{OUT}}{R_C} = 1.02\,mA$

$V_{CE2} = V_{OUT} = 1.93V$

$I_{D1} =$ 102.94 μA	$V_{DS1} =$ 4.3 V	$I_{C2} =$ 1.02 mA	$V_{CE2} =$ 1.93 V

2. If you are to design this circuit for **maximum** output swing, what should the value of R_S be? *(4 points)*

$$V_{OUT,min} = V_{GS1,min} + V_{BE} = V_{TH} + V_{BE} \quad (\text{since } V_{OUT} \text{ is same as } V_{G1})$$

$$V_{OUT,max} = V_{CC} = 5V$$

$$V_{OUT,DC} = \frac{V_{OUT,min} + V_{OUT,max}}{2} = 3.35\,V$$

$$V_{G1} = V_{OUT} = V_{GS1} + 0.7 = 3.35$$

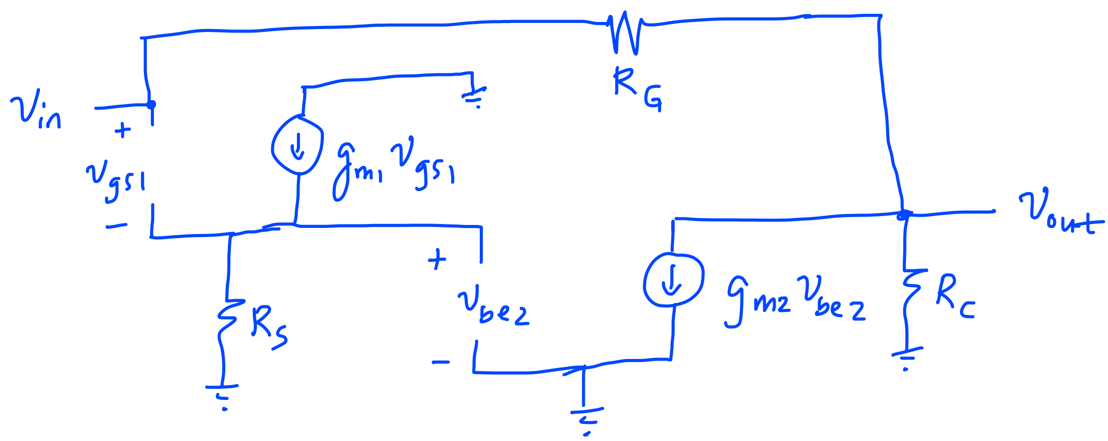
$$V_{GS1} = 2.65$$

$$I_{D1} = K(V_{GS1} - V_{TH})^2 = 5.45\text{ mA} = \frac{0.7}{R_S}$$

$$R_S = 128\,\Omega$$

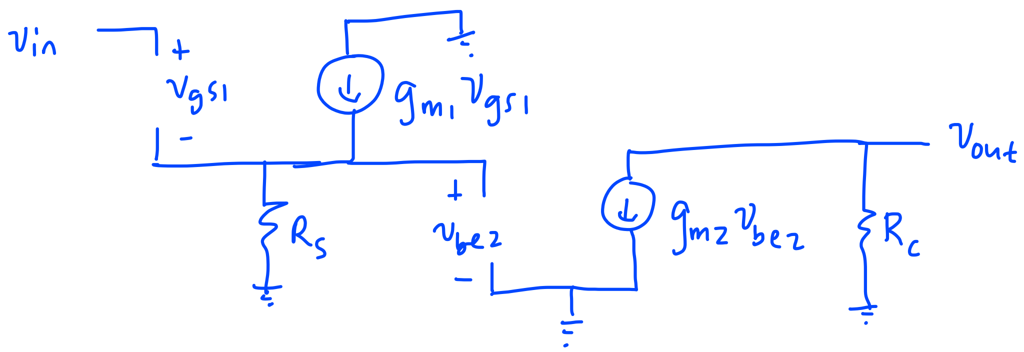
$R_S =$ 128 Ω

3. Draw the small-signal equivalent circuit of the given BiCMOS amplifier. Label completely. *(3 points)*



4. Suppose the transistors were biased so that $g_{m1} = 1\,\text{mS}$ and $g_{m2} = 50\,\text{mS}$. Determine the voltage gain of the BiCMOS amplifier given $R_S = 5.6\,\text{k}\Omega$, $R_C = 2.9\,\text{k}\Omega$, and $R_G \to \infty$. *(5 points)*

Since $R_G \to \infty$, small-signal equivalent circuit simplifies to:



KCL at v_{out}: $\quad v_{out} = -g_{m2} v_{be2} R_C$

KCL at v_{be2}: $\quad v_{be2} = g_{m1} v_{gs1} R_S$

Note that $\quad v_{gs1} = v_{in} - v_{be2}$

$$v_{be2} = g_{m1} (v_{in} - v_{be2}) R_S$$

$$v_{be2} = \frac{g_{m1} R_S}{1 + g_{m1} R_S} \cdot v_{in}$$

$$v_{out} = -g_{m2} \left(\frac{g_{m1} R_S}{1 + g_{m1} R_S} \right) R_C \quad v_{in}$$

$$\frac{v_{out}}{v_{in}} = -(50\,mS) \left(\frac{(1mS)(5600)}{1 + (1mS)(5600)} \right) (2900)$$

$v_{out}/v_{in} =$ -123

$$= -123$$