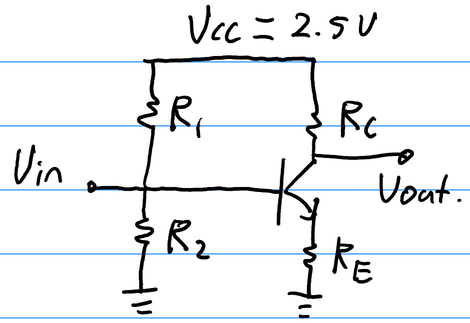
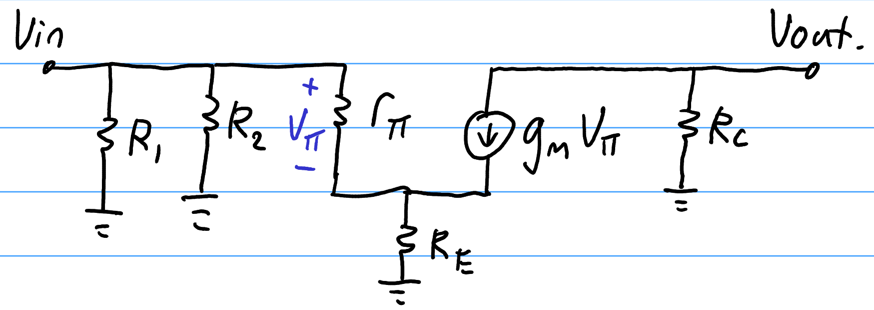
5.80



Design CE for: gain = 5
$R_{out} = 500\ \Omega$.
Assume R_E voltage drop = 0.3 V.
Current in $R_1 \approx 10\ I_B$.

Draw small signal model. $r_o = \infty \because V_A = \infty$.



Output impedance is defined with $V_{in} = 0 \therefore V_\pi = 0$
$\therefore$ Current source is open circuit $\therefore R_{out} = R_C$
$\therefore$ By the design spec, $R_{out} = 500\ \Omega \therefore R_C = 500\ \Omega$.

R_E voltage drop ≈ 0.3 V $\therefore I_E R_E = 0.3$

$$\therefore R_E = \frac{0.3}{I_E} \approx \frac{0.3}{I_C}.$$

Gain of degenerated CE $= \dfrac{-R_C}{1/g_m + R_E}$ (By circuit analysis, see lecture notes).

Also $g_m = \dfrac{I_C}{V_T}$

$$\therefore 5 = \frac{500}{\frac{0.026}{I_C} + \frac{0.3}{I_C}} = \frac{500\ I_C}{0.026 + 0.3}$$

$$\therefore I_C = 3.26\ mA.$$

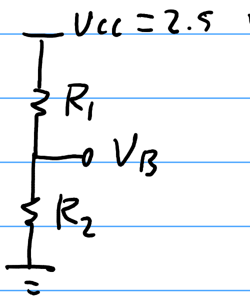
$$\therefore R_E = \frac{0.3}{I_C} = 92\ \Omega.$$

Now design the bias network.

$$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right) = 0.026 \ln\left(\frac{3.26\times10^{-3}}{6\times10^{-16}}\right)$$
$$= 0.7624 \text{ V.}$$

$$V_B = V_{BE} + V_E = 0.7624 + 0.3 = 1.0624 \text{ V.}$$

Neglecting I_B, we have a simple voltage divider.



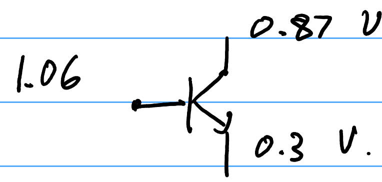
$$V_B = \frac{V_{CC} R_2}{R_1 + R_2}$$
$$1.0624\,(R_1 + R_2) = 2.5\,R_2. \quad (1)$$

The spec says $I(R_1) = 10\,I_B = 10\frac{I_C}{\beta} = 326\ \mu A.$

$$\therefore\ R_1 = \frac{2.5 - 1.0624}{326\times10^{-6}} = 4.41\text{ k}\Omega.$$

From (1): $1.0624\,(4410 + R_2) = 2.5\,R_2$
$R_2 = 3.26\text{ k}\Omega.$

Check for active region.
$V_C = 2.5 - I_C R_C = 2.5 - 3.26\times10^{-3}\times 500 = 0.87$ V.



Notice $V_C < V_B$!
$V_{BC} = -0.19$ V.

$\therefore$ In soft saturation ... this is OK but not ideal.