

Homework Assignment No. 4 - Solutions**Problem 1****13.52**

$$r_o = \frac{V_A + V_{CE}}{I_C} ; \text{ solving for } V_A : V_A = I_C r_o - V_{CE}$$

$$\text{Using the values from row 1: } V_A = 0.002(40000) - 10 = 70 \text{ V}$$

$$\text{Using the values from the second row: } \beta_o = g_m r_\pi = 0.12(500) = 60 \text{ and } \beta_F = \beta_o = 60.$$

$$\text{Row 1: } g_m = 40I_C = 40(0.002) = 0.08 \text{ S} \quad | \quad r_\pi = \frac{\beta_o}{g_m} = \frac{60}{0.08} = 750 \Omega$$

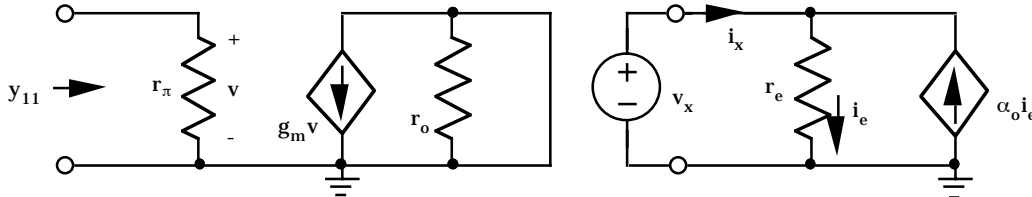
$$\mu_f = g_m r_o = 0.08(40000) = 3200$$

$$\text{Row 2: } I_C = \frac{g_m}{40} = \frac{0.12}{40} = 3 \text{ mA} \quad | \quad r_o = \frac{V_A + V_{CE}}{I_C} = \frac{80}{0.003} = 26.7 \text{ k}\Omega$$

$$\mu_f = g_m r_o = 0.12(26700) = 3200$$

$$\text{Row 3: } g_m = \frac{\beta_o}{r_\pi} = \frac{60}{4.8 \times 10^5} = 1.25 \times 10^{-4} \text{ S} \quad | \quad I_C = \frac{g_m}{40} = \frac{1.25 \times 10^{-4}}{40} = 3.13 \mu\text{A}$$

$$r_o = \frac{V_A + V_{CE}}{I_C} = \frac{80}{3.13 \times 10^{-6}} = 25.6 \text{ M}\Omega \quad | \quad \mu_f = g_m r_o = 1.25 \times 10^{-4} (25.6 \times 10^6) = 3200$$

Problem 2**13.57**

$$\text{For the hybrid pi model: } y_{11} = \frac{1}{r_\pi}$$

$$\text{For the T - model: } i_x = \frac{v_x}{r_e} - \alpha_o \frac{v_x}{r_e} = \frac{1 - \alpha_o}{r_e} v_x$$

$$y_{11} = \frac{i_x}{v_x} = \frac{1 - \alpha_o}{r_e} = \frac{1 - \frac{\beta_o}{\beta_o + 1}}{r_e} = \frac{1}{(\beta_o + 1)r_e} \rightarrow r_\pi = (\beta_o + 1)r_e$$

$$r_e = \frac{r_\pi}{(\beta_o + 1)} = \frac{\beta_o}{g_m(\beta_o + 1)} = \frac{\alpha_o}{g_m} = \frac{\alpha_o V_T}{I_C} = \frac{V_T}{I_E}$$

Problem 3**13.64**

$$(a) V_{EQ} = -9 + \frac{20k\Omega}{62k\Omega + 20k\Omega} 18 = -4.61V \quad | \quad R_{EQ} = 20k\Omega || 62k\Omega = 15.1k\Omega$$

$$I_B = \frac{-4.61 - 0.7 - (-9)}{15.1k\Omega + 136(3.9k\Omega)} = 6.76\mu A \quad | \quad I_C = 135I_B = 913\mu A$$

$$V_{CE} = 9 - 13000I_C - 3900I_E - (-9) = 2.54V$$

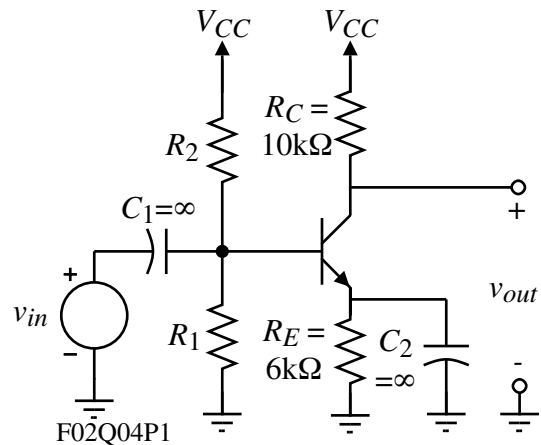
$$g_m = 40I_C = 0.0365S \quad | \quad r_\pi = \frac{135}{g_m} = 3.70k\Omega \quad | \quad r_o = \infty$$

$$A_v = -\left(\frac{2.97k\Omega}{1k\Omega + 2.97k\Omega}\right)(0.0365)(11.5k\Omega) = -314$$

$$(b) \text{ For } V_{CC} = 18V, \text{ the answers are the same: } I_C = 913\mu A \quad | \quad V_{EC} = 2.54V \quad | \quad A_v = -314$$

Problem 4

An NPN BJT common-emitter inverting amplifier is shown. Assume the parameters of the transistor are $\beta_F = 100$, $V_T = 25mV$, and $V_A = 100V$. (a.) If $I_C = 0.5mA$ and $V_{CE} = 3V$, find the small signal model parameter values for g_m , r_π and r_o . (b.) Find an algebraic expression for the small signal voltage gain, v_{out}/v_{in} . (c.) Numerically evaluate the small signal voltage gain, v_{out}/v_{in} .

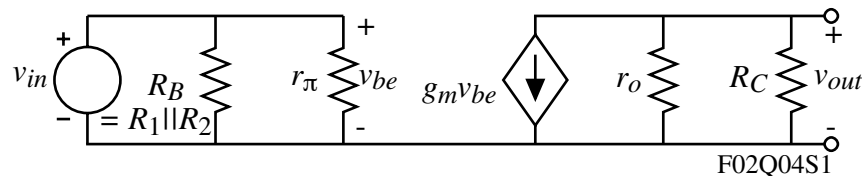
Solution

$$(a.) \quad g_m = \frac{I_C}{V_T} = \frac{0.5mA}{25mV} = \underline{20mS}$$

$$r_\pi = \beta_F \frac{V_T}{I_C} = \frac{100}{20mS} = \underline{5k\Omega}$$

$$r_o = \frac{V_A + V_{CE}}{I_C} = \frac{102}{0.5mA} = \underline{204k\Omega}$$

(b.) To find the small signal voltage gain, we must first develop a small signal model. This model is given below:



$$\boxed{\frac{v_{out}}{v_{in}} = \frac{v_{out}}{v_{be}} = -g_m(r_o || R_C)}$$

(c.) The numerical value of this gain is

$$\frac{v_{out}}{v_{in}} = -20mS(204k\Omega || 10k\Omega) = -20mS(9.53k\Omega) = \underline{-190.65 \text{ V/V}}$$