

Homework Assignment No. 4 - Solutions**13.40**

$$\frac{r_D}{20\text{k}\Omega + r_D} = \frac{1}{10} \rightarrow r_D = 2.22\text{k}\Omega \quad | \quad 40I_D = \frac{1}{2.22\text{k}\Omega} \rightarrow I_D = 11.3 \mu\text{A} \quad | \quad v_s = 10(5\text{mV}) = 50 \text{ mV}$$

13.44

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

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

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

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

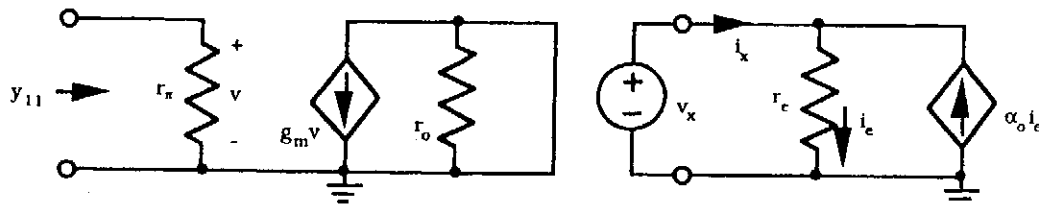
$$\mu_F = g_m r_o = 0.08(40000) = 3200$$

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

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

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

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

13.50

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

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

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

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

13.57

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

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

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

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

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

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

13.59

$$g_m = 40(50\mu\text{A}) = 2.00\text{mS} \quad | \quad r_\pi = \frac{100}{2.00\text{mS}} = 50\text{k}\Omega \quad | \quad r_o = \frac{75\text{V} + 10\text{V}}{50\mu\text{A}} = 1.70\text{M}\Omega$$

$$R_{BB} = 100\text{k}\Omega \parallel 50\text{k}\Omega = 33.3\text{k}\Omega$$

$$A_v = -\left(\frac{33.3\text{k}\Omega}{33.3\text{k}\Omega + 0.75\text{k}\Omega}\right)(2\text{mS})(1.70\text{M}\Omega \parallel 100\text{k}\Omega \parallel 100\text{k}\Omega) = -95.0$$