EECS 245 HMwk 5 Sol'n

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4.42 From pg 250, $r_\pi = \frac{\beta V_T}{I_{CQ}}$ & $g_m = \frac{\beta}{r_\pi} = \frac{I_{CQ}}{V_T}$

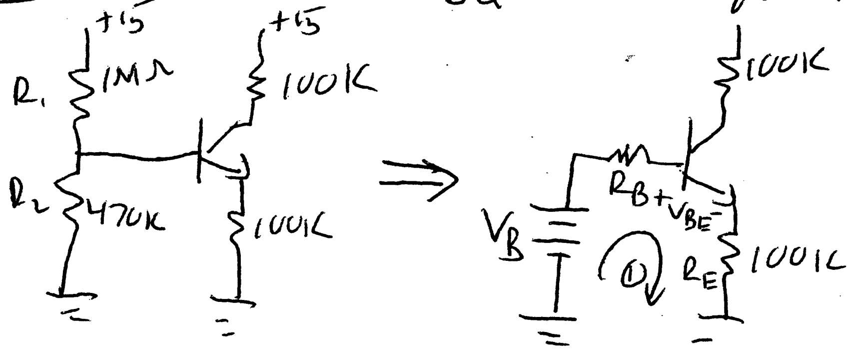
$V_T \approx 26mV$, $\beta = 100$ ∴ we get the following:

I_{CQ}	r_π	g_m
1uA	2.6MΩ	38.5uS
0.1mA	26 kΩ	3.85mS
1mA	2.6 kΩ	38.5mS

Note: unit for g_m, mS, is milli Siemens, not milliseconds. $\boxed{\text{Siemen: } S = \frac{\text{Amp}}{\text{Volt}}}$

2

4.46 First, find I_{BQ} w/ DC equivalent circuit: *Allegvations from Section 4.7 *



$V_B = \frac{15(470K)}{470K + 1M} = \underline{4.8V = V_B}$

$R_B = R_1 \| R_2 = \frac{470K(1M)}{470K + 1M}$

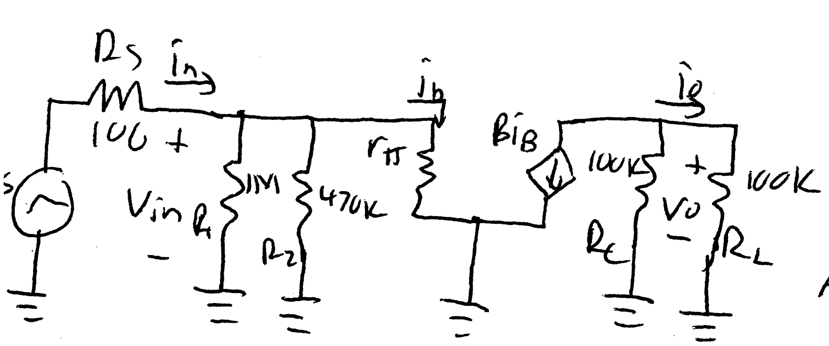
$\underline{R_B = 320\ K\Omega}$

2

KCL around ①: $V_B = I_B R_B + V_{BE} + I_E R_E$ $\quad I_E = (\beta+1) I_B \quad V_{BE} = 0.7$

$I_B = \frac{V_B - V_{BE}}{R_B + (\beta+1)R_E}$ $\quad \underline{I_{BQ} = 0.393uA}$ $\quad I_{CQ} = \beta I_{BQ}$ $\boxed{I_{CQ} = 39.3uA}$

Small signal model: (see next problem for how to draw SSm's)



$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{100(26mV)}{39.3uA} = \boxed{66.2 K\Omega}$ $\boxed{V_\pi}$

$\underline{R_L' = R_L \| R_C = 50\ K\Omega}$ ∴

$A_v = \frac{-\beta R_L'}{r_\pi + (\beta+1)R_E}$ $\quad R_E = 0$ ∴ $A_v = \frac{-\beta R_L'}{r_\pi}$

$\boxed{A_v = -75.5}$ $\quad A_{v_o} = \frac{-\beta R_C}{r_\pi} = \boxed{-151 = A_{v_o}}$ $\quad Z_{in} = \frac{1}{\frac{1}{R_B} + \frac{1}{r_\pi + (\beta+1)R_E}} =$

$\frac{1}{\frac{1}{320K} + \frac{1}{66.2K}}$ $\boxed{Z_{in} = 54.8 K\Omega}$ $\quad A_i = \frac{A_v Z_{in}}{R_C} = \frac{(-75.5)(54.8K)}{100K} = \boxed{-41.4 = A_i}$

2

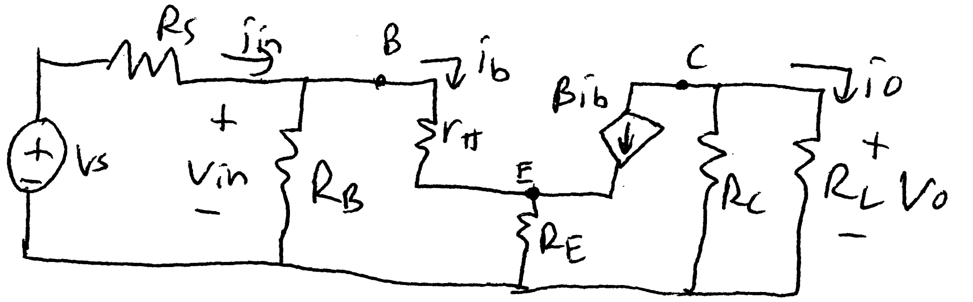
$G = A_i A_v$ $\boxed{G = 3,126}$ $\quad Z_o = R_C$ $\boxed{Z_o = 100K\Omega}$

4.49 In writing small signal models, remember the following rules:

1) All DC voltage sources become short circuits & current sources becomes open circuits

2) All capacitors become short circuits 3) BJT's are replaced w/ model on pg 251

a)



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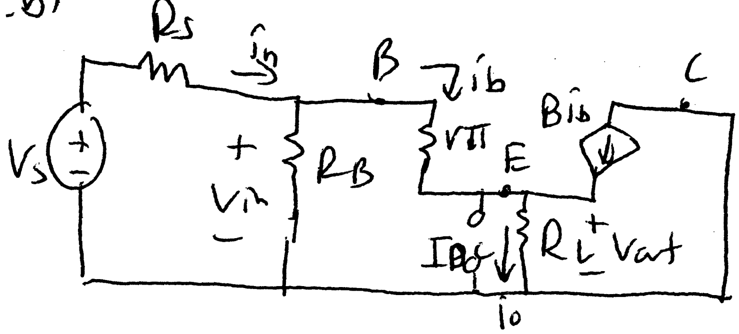
(b)



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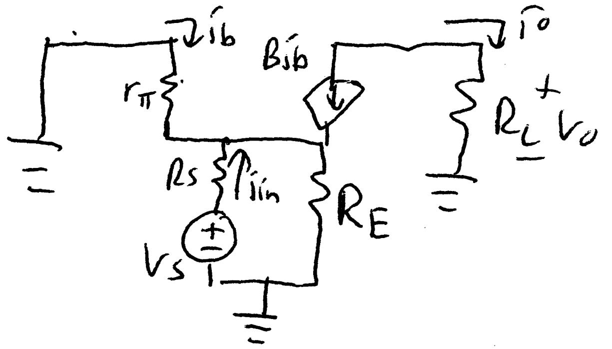
c)



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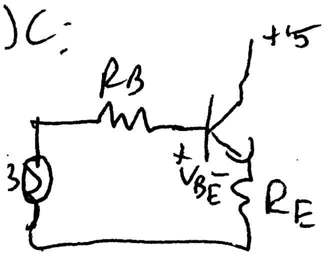
4.52 All equations come from section 4.8 directly → Same circuit! 2

DC:



$V_B = \frac{15(1M)}{1M+1M} = 7.5 \quad R_B = 1M // 1M = 500k$

$I_{CQ} = \beta I_{BQ} = 100\left(\frac{7.5-0.7}{500k+(100+1)100k}\right)$ $\boxed{I_{CQ} = 64.1uA}$

$r_\pi = \frac{\beta V_T}{I_{CQ}}$ $\boxed{r_\pi = 40.56 k\Omega}$ $R_L' = 100k // 50k$ $\underline{R_L' = 33.3k\Omega}$

$A_v = \frac{R_L'(\beta+1)}{r_\pi + R_L'(\beta+1)} = \boxed{A_v = 0.988}$ $A_{vo} = \frac{R_E(\beta+1)}{r_\pi + R_E(\beta+1)} = \boxed{A_{vo} = 0.996}$ $R_s' = R_B // R_s$ $\underline{R_s' = 83.3k\Omega}$

$Z_{in} = R_B // (r_\pi + R_L'(\beta+1))$ $\boxed{Z_{in} = 436k\Omega}$ $A_i = \frac{A_v Z_{in}}{R_L}$ $\boxed{A_i = 8.61}$ 2

$G = A_v A_i$ $\boxed{G = 8.51}$ $Z_o = R_E // \left(\frac{R_s' + r_\pi}{\beta+1}\right) = \boxed{Z_o = 1.21k\Omega}$

7.56 Small signal equivalent:

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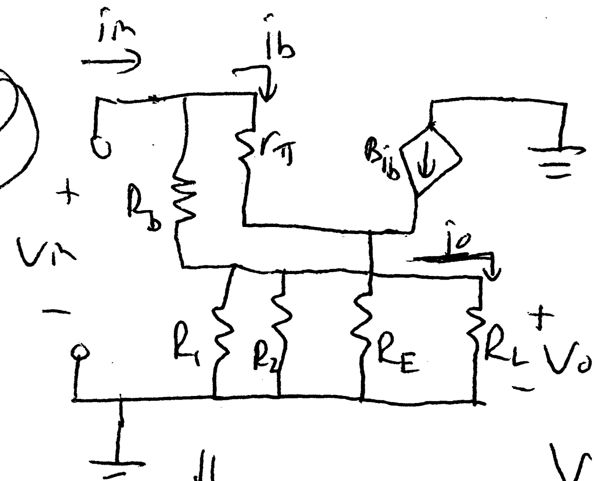
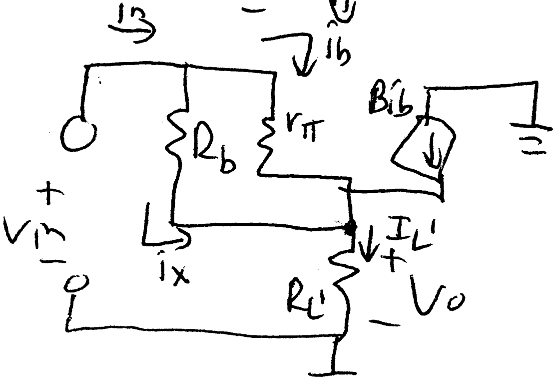




First, combine bottom 4 resistors:

$$R_L' = R_1 // R_2 // R_E // R_L$$

$$V_o = i_L'(R_L')$$

$$i_L' = i_b + \beta i_b + i_x$$

$$i_x = \frac{i_b r_\pi}{R_B} \therefore$$

$$V_o = R_L'\left(i_b + \beta i_b + \frac{r_\pi i_b}{R_B}\right)$$

$$V_{in} = V_o + r_\pi i_b \therefore$$

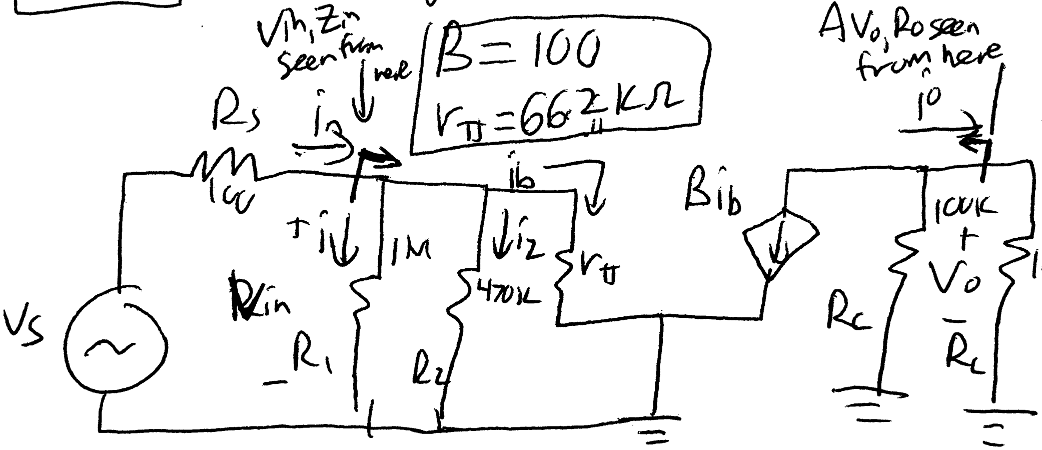
$$A_v = \frac{V_o}{V_{in}} = \boxed{\frac{R_L'\left(1+\beta+\frac{r_\pi}{R_B}\right)}{r_\pi + R_L'\left(1+\beta+\frac{r_\pi}{R_B}\right)} = A_v}$$

$$i_{in} = \frac{V_{in}-V_o}{R_B // R_\pi} = \frac{V_{in} - A_v V_{in}}{R_B // R_\pi} \qquad Z_{in} = \frac{V_{in}}{i_{in}} = \frac{V_{in}}{\frac{V_{in}-A_v V_{in}}{R_B // R_\pi}}$$

2

$$\boxed{Z_{in} = \frac{R_B // R_\pi}{1 - A_v}}$$

4.46 Small signal analysis in depth → much like section 4.7



Let $R_L' = R_C // R_L$

$R_L' = 50K\Omega$

Let $R_b = R_1 // R_2$

$R_b = 320K\Omega$

$A_v = \frac{V_o}{V_{in}}$ $\quad V_o = i_o R_L' = -B i_b R_L'$ $\quad V_{in} = i_b r_\pi$ $\therefore \frac{V_o}{V_{in}} = \frac{-B \cancel{i_b} R_L'}{\cancel{i_b} r_\pi} = \boxed{-75.5}$

A_{vo}, $V_o = i_o R_C \therefore$ $\quad \frac{V_o}{V_{in}} = \frac{-B R_L \cancel{i_b}}{\cancel{i_b} r_\pi} = \boxed{-151}$

$Z_{in} = \frac{V_{in}}{i_{in}}$ $\quad i_{in} = i_1 + i_2 + i_b = \frac{V_{in}}{R_1} + \frac{V_{in}}{R_2} + \frac{V_{in}}{R_b} \therefore \frac{V_{in}}{i_{in}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_B}} = \boxed{54.8K\Omega}$

$A_i = \frac{i_o}{i_{in}}$ $\quad A_v \cdot Z_{in} = \left(\frac{V_o}{V_{in}}\right)\left(\frac{V_{in}}{i_{in}}\right) = \frac{V_o}{i_{in}}$ $\quad V_o = i_o R_C \therefore A_i = \frac{A_v \cdot Z_{in}}{R_C}$

$\boxed{A_i = -41.4}$ Note Ai does not depend on R_L. In reality, it does, but this quantity measures current gain independent of R_L

$G = A_i \cdot A_v = \boxed{3,126}$ $\quad Z_o = \frac{V_o}{i_o} = R_C = \boxed{100K\Omega}$