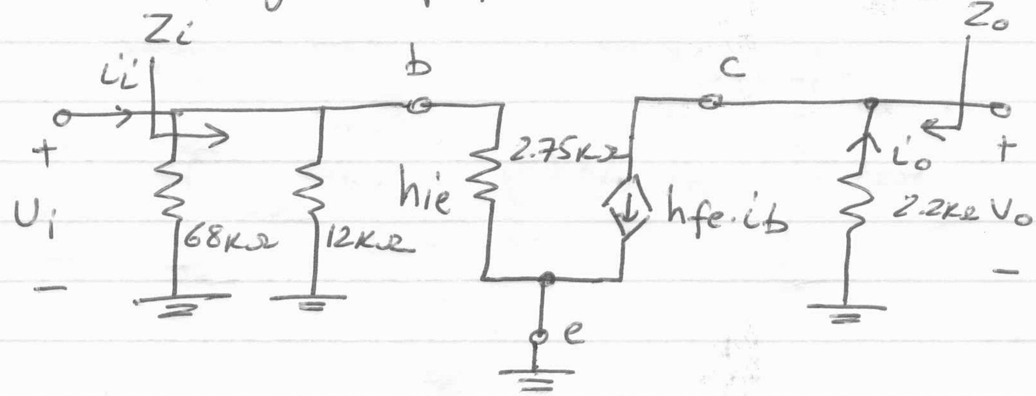
Solutions BJT AC Analysis

Q23. using simplified BJT small signal model



(a) $Z_i = 68k\Omega // 12k\Omega // hie =$

$Z_o = 2.2k\Omega$

(b) $A_v = \frac{V_o}{V_i} = \frac{V_o}{i_b} \cdot \frac{i_b}{U_i} = -hfe \cdot 2.2k\Omega \cdot \frac{1}{2.75k\Omega} = -144$

$V_o = -hfe \cdot i_b \cdot 2.2k\Omega$

$i_b = \frac{U_i}{hie}$

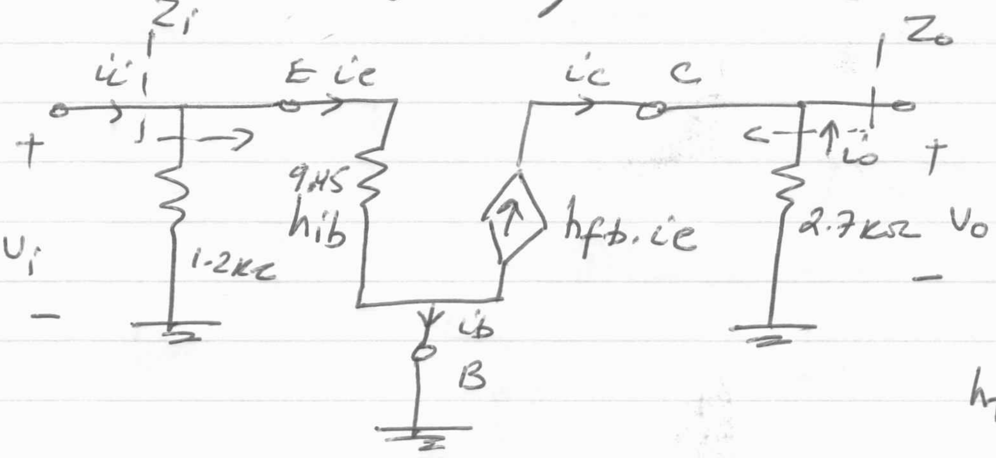
$A_i = \frac{i_o}{i_i} = \frac{i_o}{i_b} \cdot \frac{i_b}{i_i} = \frac{hfe \cdot 10.2k\Omega}{10.2k\Omega + 2.75k\Omega} =$

$i_o = hfe \cdot i_b$

$i_b = i_i \cdot \frac{(68k\Omega // 12k\Omega)}{(68k\Omega // 12k\Omega) + hie} = 141.776$

Q23.

ac small signal equivalent circuit



$h_{fb} = 0.992$

(a) $Z_i = 1.2k\Omega // 9.45\Omega = 9.38\,\Omega$

$Z_o = 2.7k\Omega$

(b) $A_v = \frac{V_o}{V_i} \Rightarrow A_v = h_{fb} \cdot 2.7k\Omega \cdot \frac{1}{h_{ib}} = \frac{0.992 \cdot 2.7k\Omega}{9.45\Omega}$

$= 283.43$

$V_o = h_{fb} \cdot i_e \cdot 2.7k\Omega$

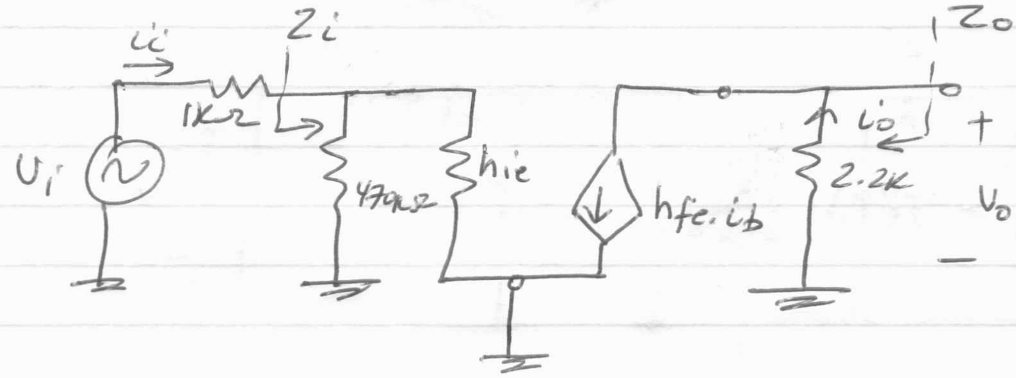
$i_e = \frac{V_i}{h_{ib}}$

$A_i = \frac{i_o}{i_i} \Longrightarrow A_i = -h_{fb} \cdot \frac{1.2k\Omega}{1.2k\Omega + 9.45\Omega} = -0.9842$

$i_o = -h_{fb} \cdot i_e$

$i_e = \frac{1.2k\Omega}{1.2k\Omega + 9.45\Omega} \cdot i_i$

Q25. ac small signal equivalent circuit



a) $Z_i = 470k\Omega \,//\, hie = 470k\Omega \,//\, 0.86\,k\Omega = 0.858\,k\Omega$

d) $Z_o = 2.2k\Omega$

b) $A_V = \dfrac{V_o}{V_i} \implies A_V = -h_{fe} \cdot \dfrac{470K}{470K + hie} \cdot \dfrac{1 \cdot 2.2K}{0.858k\Omega + 1k\Omega} = -165.47$

$V_o = -h_{fe} \cdot i_b \cdot 2.2K$

$i_b = i_i \cdot \dfrac{470k\Omega}{470k\Omega + hie}$

$i_i = \dfrac{V_i}{Z_i + 1K} = \dfrac{V_i}{0.858k\Omega + 1k\Omega}$

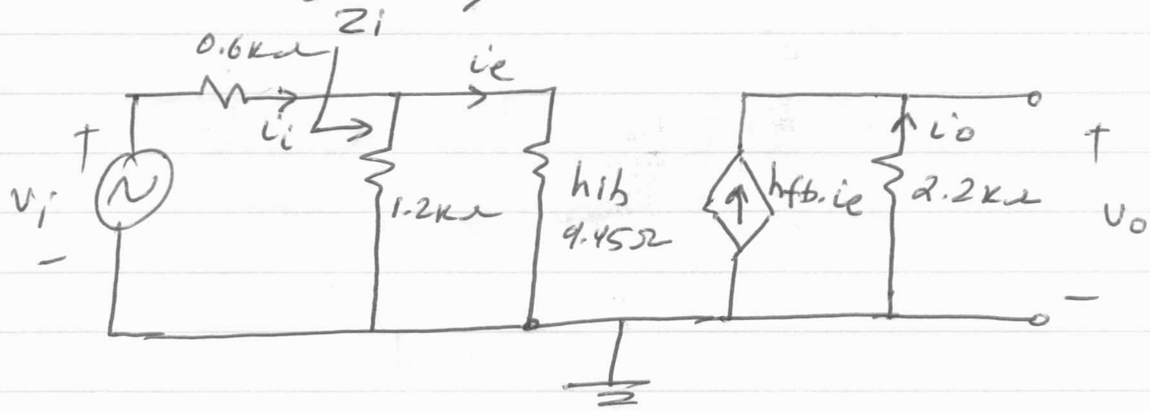
$\underline{\underline{A_V = -165.47}}$

c) $A_i = \dfrac{i_o}{i_i} \implies A_i = h_{fe} \cdot \dfrac{470k\Omega}{470k\Omega + hie} = 139.774$

$i_o = h_{fe} \cdot i_b$

$i_b = i_i \cdot \dfrac{470k\Omega}{470k\Omega + hie}$

Q26. ac small signal equivalent circuit



a) $Z_i = 1.2k\Omega \,//\, h_{ib} = 1.2k\Omega \,//\, 9.45\Omega = 9.38\,\Omega$

b) $A_i = \frac{i_o}{i_i} \Longrightarrow A_i = \frac{i_o}{i_e} \cdot \frac{i_e}{i_i} = -h_{fb} \cdot \frac{1.2k\Omega}{1.2k\Omega + 9.45\Omega}$

$i_o = -h_{fb} \cdot i_e$

$i_e = i_i \cdot \frac{1.2k\Omega}{1.2k\Omega + h_{ib}}$

$= -0.947 \cdot 0.992$

$= -0.989$

c) $A_v = \frac{v_o}{v_i} \Longrightarrow A_v = \frac{v_o}{i_e} \cdot \frac{i_e}{i_i} \cdot \frac{i_i}{v_i}$

$v_o = +h_{fb} \cdot i_e \cdot 2.2k\Omega$

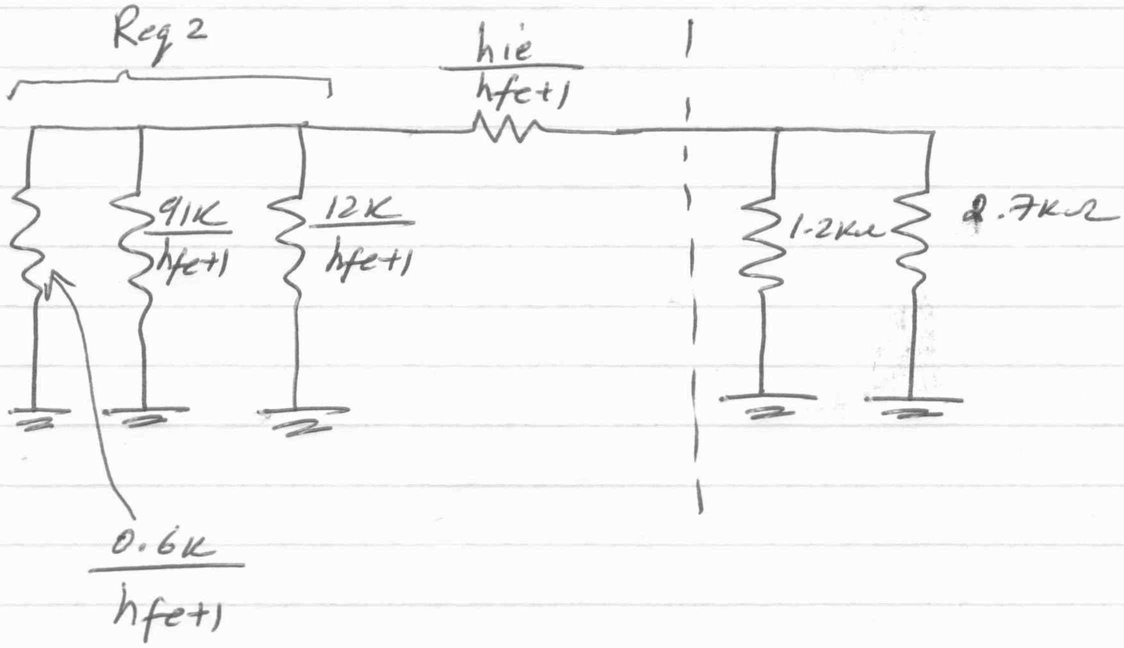
$i_e = i_i \cdot \frac{1.2k\Omega}{1.2k\Omega + 9.45\Omega}$

$i_i = \frac{v_i}{0.6k\Omega + Z_i}$

$= -h_{fb} \cdot 2.2k\Omega \cdot \frac{1.2k\Omega}{1.2k\Omega + 9.45} \cdot \frac{1}{0.6k + Z_i}$

$=$

3) Z_o $\rightarrow$ need to reflect all impedances from base to emitter ~~by multipl~~



note that input source V_i was shorted

$$Z_o = (2.7K \,//\, 1.2K\Omega) \,//\, \left(\frac{h_{ie}}{h_{fe}+1} + R_{eq2}\right)$$

<u>where</u>

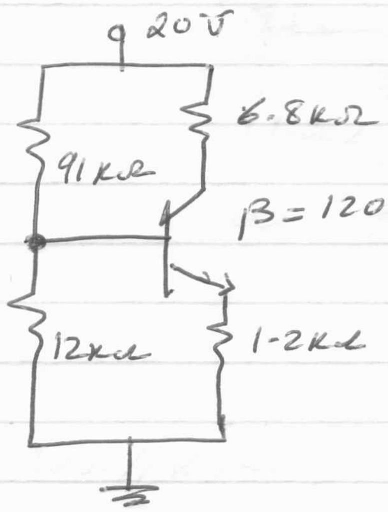
$$R_{eq2} = \frac{12K}{h_{fe}+1} \,//\, \frac{91K}{h_{fe}+1} \,//\, \frac{0.6K}{h_{fe}+1}$$

Q10.

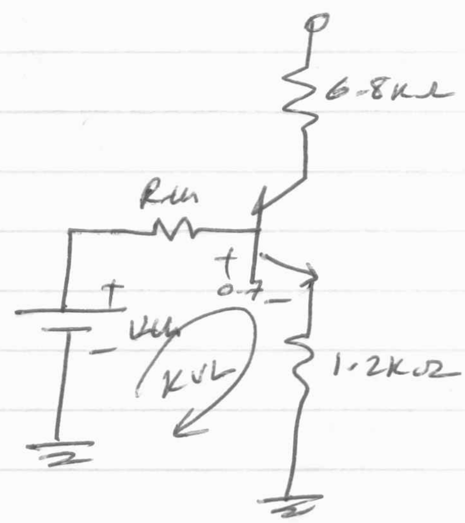
DC analysis is required to find hie?

where $h_{ie} = \dfrac{V_T}{I_{BQ}}$, $V_T \cong 26\,mV$

DC equivalent circuit (all caps are open & ac sources = 0)



Thevenin's ⟹ Equivalent



where $V_{th} = \dfrac{12k\Omega}{12k\Omega + 91k\Omega} \cdot 20 = 2.33\ V$

$R_{th} = 91k\Omega // 12k\Omega = 10.6\,k\Omega$

<u>KVL for input loop</u>

$V_{th} - I_B R_{th} - 0.7 - I_B(\beta+1)\cdot 1.2k\Omega = 0 \Rightarrow$

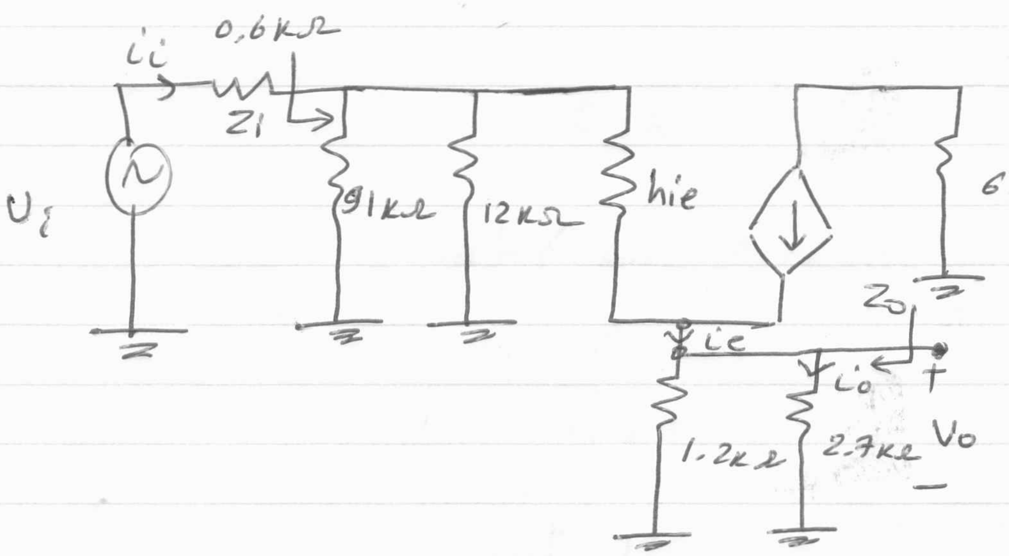
$I_{BQ} = \dfrac{V_{th} - 0.7}{R_{th} + 1.2k\Omega(\beta+1)} = \dfrac{2.33 - 0.7}{10.6k\Omega + 1.2k\Omega \cdot 121}$

$= 10.46\ \mu A$

$h_{ie} = \dfrac{26\,mV}{10.46\,\mu A} = 2485\ \Omega$

Now ac equivalent circuit

$h_{fe} = \beta = 120$
$h_{ie} = 2485$



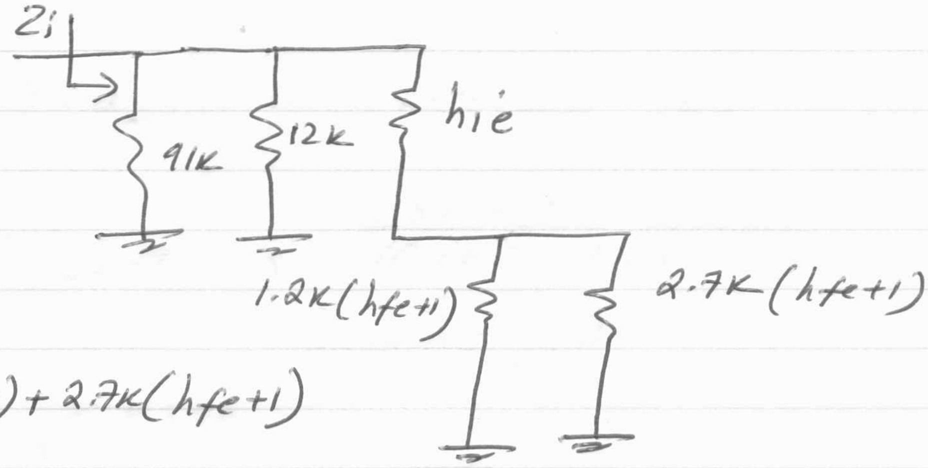
1) $A_v = \dfrac{V_o}{V_i}$

$V_o = i_e(1.2k\Omega \,//\, 2.7k\Omega)$

$i_e = i_b(h_{fe}+1)$

$i_b = \dfrac{V_i}{0.6k\Omega + Z_i}$

2) $Z_i \rightarrow$ need to reflect the 1.2kΩ & 2.7kΩ from emitter to base



$Z_i = 12K // 91K // [R_{eq1}]$

$R_{eq1} = h_{ie} + 1.2K(h_{fe}+1) + 2.7K(h_{fe}+1)$