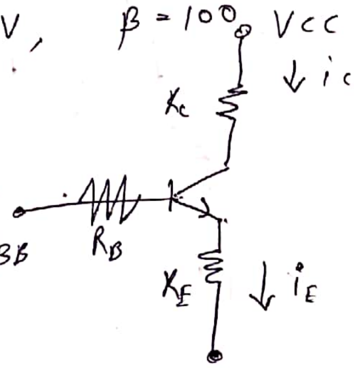
Adwait Naravane
19MS151

PH3104
PS - 8.

Q1 (a) $R_1 = 10k$, $R_2 = 3.3k$, $R_C = R_E = 1k$, $R_L = 10k$,
$V_{CC} = 12V$, $V_{BE} = 0.7V$, $\beta = 100$



$R_L' = \frac{1 \times 10k^2}{11k} = \frac{10}{11}k.$

$R_B = \frac{10(3.3)}{13.3} = 2.48k.$

$V_{BB} = \frac{3.3}{13.3}(12) = 2.98.$

$V_{BB} = i_B R_B + V_{BE} + i_E R_E.$

$= I_B R_B + V_{BE} + (\beta+1) I_B R_E$

$I_B = \frac{V_{BB} - V_{BE}}{R_B + (\beta+1) R_E} = 0.022 \, mA.$

$I_C = \beta I_B = 2.2 \, mA$, $I_E = -(\beta+1) i_B = -2.22 \, mA.$

$V_{CC} = R I_C + V_{CE} - I_E R_E$

$V_{CE} = V_{CC} - I_C R_C + I_E R_E = 12 - 2.2 - 2.22$

$V_{CE} = \underline{7.578 \, V}$

$V_{BC} = V_{BE} + V_{EC} = V_{BE} - V_{CE} = \underline{-6.878 \, V}$

(b). $h_{fe} = 200$, $h_{ie} = 2.2$, $h_{oe} = 1.8 \times 10^{-4} \Omega^{-1}$
$h_{re} = 1.2 \times 10^{-5}$, $R_L' = \frac{R_C R_L}{R_C + R_L} = \frac{10}{11}k.$

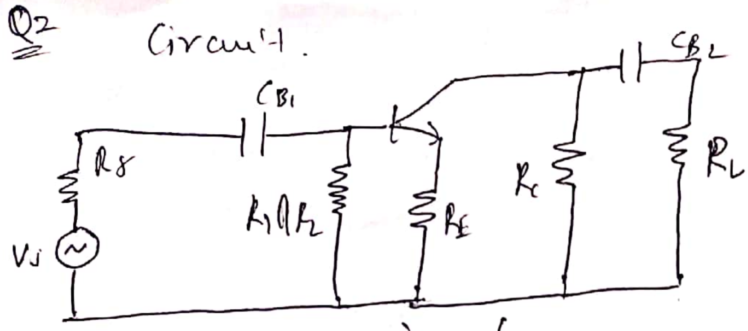
$A_i = \frac{-h_{fe}}{1 + R_L' h_{oe}} = \frac{-200}{1 + \frac{1.8}{11}} = 176.$

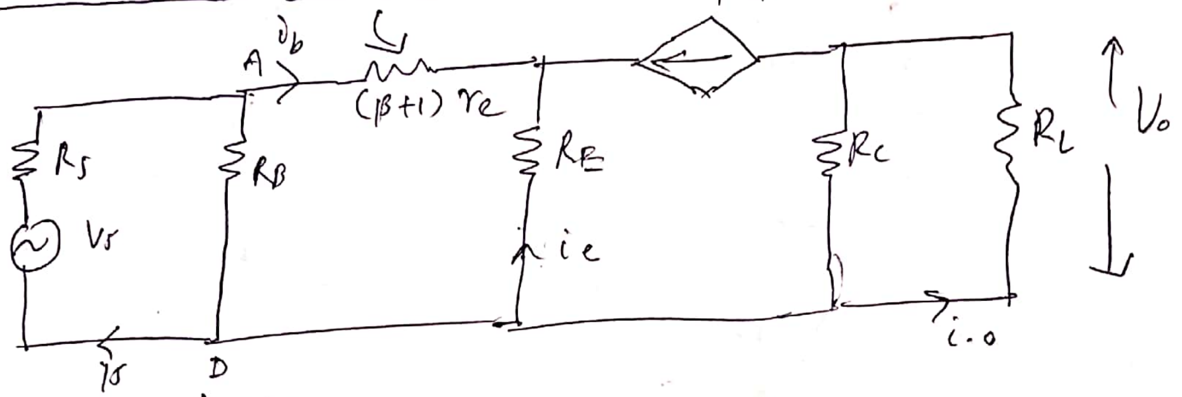
$A_{V_1} = \frac{V_{CE}}{V_S} = \frac{7.578}{V_S}$

$A_{i_L} = \frac{R_C}{R_C + R_L} A_i = 16.$

$V_S \Rightarrow$ source voltage

Q2 Circuit.





$Z_i \Rightarrow$ input impedence.

$Z_i = (R_1 \| R_2) \| (R_E + (\beta+1) \cancel{R_E})$

$Z_o \Rightarrow$ output impedence $= R_C$.

$V_i = (\beta+1) i_b (r_e + R_E)$.

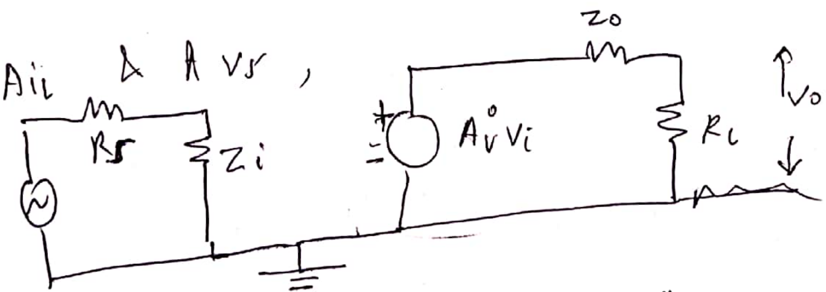
$V_{output} = -\beta i_b (R_C \| R_L)$.

$\rightarrow$ Volt Gain $=$ $A_v = \dfrac{V_o}{V_i} = -\dfrac{\beta (R_C \| R_L)}{(\beta+1) i_b (r_e + R_E)} = -\dfrac{\alpha (R_C \| R_L)}{r_e + R_E}$.

$\Rightarrow$ Load Gain $=$ $A_v^o = A_v|_{R_L \to \infty} = -\dfrac{\alpha R_C}{r_e + R_E}$.

$A_i = \dfrac{-i_c}{i_b} = -\beta$.

for A_{iL} & A_{vs},



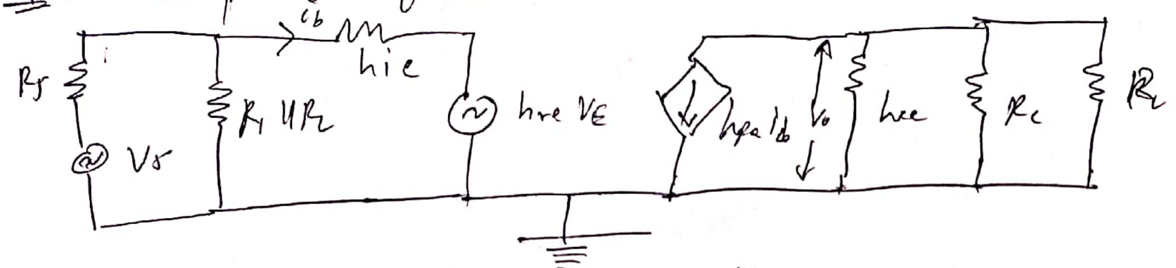
$V_o = \dfrac{R_L}{R_L + Z_o} A_v^o V_i = \dfrac{R_L}{R_L + Z_o} \cdot \dfrac{Z_i}{R_s + Z_i} A_v^o$

$\Rightarrow V_i = \dfrac{Z_i}{R_s + Z_i} V_s$.

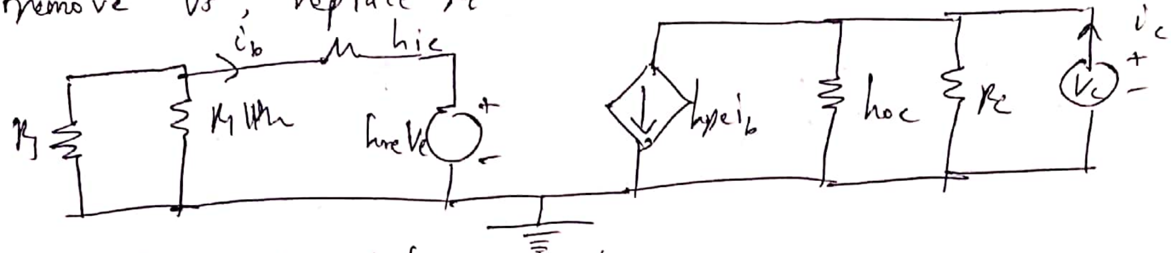
$A_{vs} = \dfrac{V_o}{V_s} = \left(\dfrac{R_L}{R_L + Z_o}\right)\left(\dfrac{Z_i}{R_s + Z_i}\right) A_v^o$

$A_{iL} = \dfrac{-R_C}{R_C + R_L} A_i = \dfrac{-\beta R_C}{R_C + R_L}$

Q3 h-para equivalent.



remove V_s, replace R_L with V_o.



$V_B = V_i = 0$, $V_i = i_b h_{ie} + V_o h_{re} = 0$

$$i_b = -\frac{h_{re} V_o}{h_{ie}}$$

output impedence $Z_o = \frac{V_o}{I_o}$

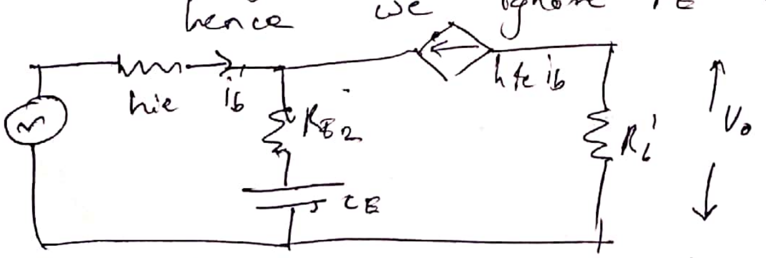
$$\left(i_o - h_{fe} i_b\right)\left(\frac{1}{h_{oe}} \parallel R_c\right) = V_o$$

$$i_o\left(\frac{1}{h_{oe}} \parallel R_c\right) = V_o + h_{fe} i_b\left(\frac{1}{h_{oe}} \parallel R_c\right)$$

$$i_o\left(\frac{1}{h_{oe}} \parallel R_c\right) = V_o - \frac{h_{fe} h_{re}}{h_{ie}} V_o\left(\frac{1}{h_{oe}} \parallel R_c\right)$$

$$\Rightarrow Z_o = \frac{V_o}{I_o} = \frac{\left(\frac{1}{h_{oe}} \parallel R_c\right)}{\left(1 - \frac{h_{re} h_{fe}}{h_{ie}}\left(\frac{1}{h_{oe}} \parallel R_c\right)\right)}$$

Q4 At mid band frequencies, current will largely pass through C_E arm due to low impedence. hence we ignore R_E arm.



$V_s = i_b(1+h_{fe})\left(R_{E2} + \frac{1}{j\omega C_E}\right) + i_b h_{ie}$

$V_o = -h_{fe} i_b R_L'$

$R_L' = R_L \parallel R_c$, $A_v = \frac{V_o}{V_s} = \frac{-h_{fe} R_L'}{h_{ie} + (1+h_{fe})\left(R_{E2} + \frac{1}{j\omega C_E}\right)}$

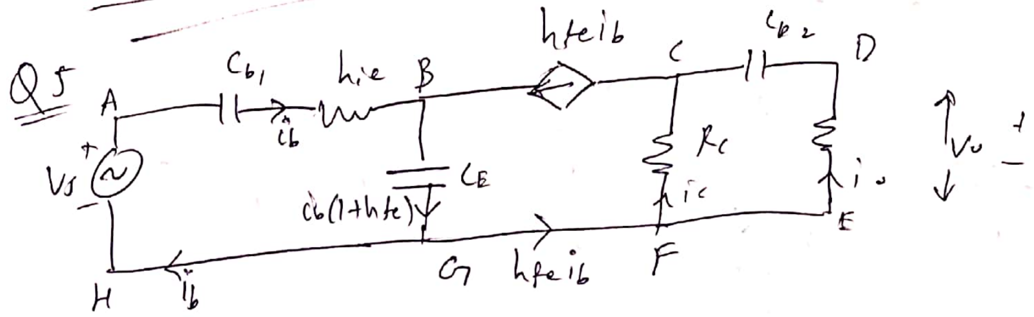
$$A_v = \frac{-h_{fe} R_L'}{h_{ie} + (1+h_{fe}) R_{E2}} \cdot \frac{1}{\left(1 + \frac{1}{j\omega C_E\left(\frac{h_{ie} + R_{E2}(1+h_{fe})}{1+h_{fe}}\right)}\right)}$$

$$f_{cutoff} = \frac{1+h_{fe}}{2\pi C_E\left(h_{ie} + R_{E2}(1+h_{fe})\right)}$$

$f_{cutoff}(R_{E_2}=0) > f_{cutoff}(R_E \neq 0)$

Av mid-band width increases.

Q5



$i_c = h_{fe}i_b - i_o$

KCL to full.

$$\frac{i_b}{j\omega C_b} + h_{ie}i_b + \frac{i_b(1+h_{fe})}{j\omega C_E} = V_s$$

$$R_C \parallel \left(R_L + \frac{1}{j\omega C_{b2}}\right) \Rightarrow i_o = \frac{h_{fe}\, i_b R_C}{R_C + R_L + \frac{1}{j\omega C_{b2}}}$$

$$V_o = -i_o R_L = \frac{-h_{fe}\, i_b R_C R_L}{R_C + R_L + \frac{1}{j\omega C_{b2}}}$$

$$\frac{V_o}{V_s} = \frac{\dfrac{-h_{fe}\, i_b R_C R_L}{R_C + R_L + \frac{1}{j\omega C_{b2}}}}{\dfrac{i_b}{j\omega C_{b1}} + h_{ie}i_b + \dfrac{i_b(1+h_{fe})}{j\omega C_E}}$$

$$= \frac{-h_{fe} R_C R_L}{h_{ie}(R_C+R_L)\left(1 + \frac{1}{j\omega C_{b2}(R_C+R_L)}\right)\left(1 + \frac{1}{j\omega h_{ie}}\left(\frac{h_{fe}+1}{C_E} + \frac{1}{C_{b2}}\right)\right)}$$

$$A_v'|_{mid-b} = \frac{h_{fe} R_C R_L}{h_{ie}(R_C+R_L)}$$

$$A_v = \frac{A_v'|_{m.b}}{\left(1 + \frac{1}{j\omega C_{b2}(R_L+R_C)}\right)\left(1 + \frac{h_{fe}+1}{C_E} + \frac{1}{C_{b1}}\right)}$$

$C_E \simeq C_{b1} \simeq C_{b2}$

$$\frac{1}{\omega C_{b2}(R_C+R_L)}, \frac{1}{\omega C_{b1} h_{ie}} < \frac{h_{fe}+1}{\omega h_{ie} C_E}$$

C_E determines the cutoff frequency.

$\alpha = C_{b2}(R_C+R_L) \Rightarrow \beta = h_{ie} \Big/ \frac{h_{fe}}{C_E} + \frac{1}{C_{b1}}$

$$A_v = A_v'|_{m.b} \Big/ \left(1 + \frac{1}{j\omega C}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) - \frac{1}{\omega^2 \alpha\beta}\right)$$

Now for 3 dB freq ω_0,

$\|$ denominator $\| = 2$.

$$\Rightarrow \left(1 - \frac{1}{\omega_0^2 \alpha\beta}\right)^2 + \frac{1}{\omega_0^2}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)^2 = 4$$

$$1 - \frac{2}{\omega_0^2 \alpha\beta} + \frac{1}{\omega_0^4 \alpha^2\beta^2} + \frac{1}{\alpha^2} + \frac{1}{\beta^2} + \frac{2}{\alpha\beta} = 4.$$

$$1 + \frac{1}{\omega_0^2 \alpha^2\beta^2} + \frac{1}{\omega_0^2\alpha^2} + \frac{1}{\omega_0^2\beta^2} = 2$$

$$\boxed{1 + \omega_0^2 \alpha^2 + \omega_0^2 \beta^2 - \omega_0^4 \alpha^2\beta^2 = 0}$$