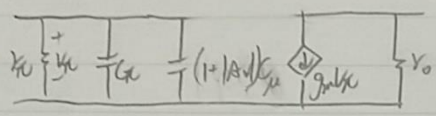
國立臺灣科技大學答案卷
National Taiwan University of Science and Technology Answer Sheet

姓名/Name 張恒豪　學號/Student ID B11002110　班級/Class 四電子二乙
科目/Course title 電子學　日期/Date 112.3.29

| 評分 Score | 教師簽章 Signature of Lecturer |
|---|---|
| 85 | |

記分欄　從此處開始寫起。試卷用紙務須節用，非經主試認可不得續用其他紙張作答。/Please write from here.

1.



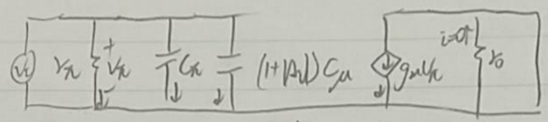

$A_V = |-g_m r_o|$

$\boxed{f_B} = \frac{1}{2\pi}\cdot\frac{1}{(\tau_{p\pi}+\tau_{p\mu})}$

$\tau_{p\pi} = r_\pi C_\pi$

$\tau_{p\mu} = r_\pi(1+g_m r_o)C_\mu$

$= \boxed{\frac{1}{2\pi r_\pi[C_\pi+(1+g_m r_o)C_\mu]}\ Hz}$ #1




求使 $\left|\frac{V_o}{V_i}\right|=0$ 的頻率 ⇒ 等同於輸出端短路

$g_m V_\pi + \frac{V_\pi}{\frac{1}{2\pi f_T(1+|A_V|)C_\mu}} + \frac{V_\pi}{\frac{1}{2\pi f_T C_\pi}} + \frac{V_\pi}{r_\pi} = 0$

$g_m + 2\pi f_T\left((1+|A_V|)C_\mu + C_\pi\right) + \frac{1}{r_\pi} = 0$

⇒ $2\pi f_T\left((1+|A_V|)C_\mu + C_\pi\right) = -\frac{1}{r_\pi} - g_m$

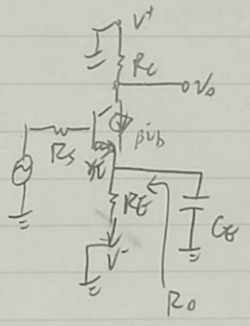
⇒ $f_T = \frac{-\frac{1}{r_\pi} - g_m}{2\pi[(1+|A_V|)C_\mu + C_\pi]}$

⇒ $\boxed{|f_T| = \left|\frac{g_m+\frac{1}{r_\pi}}{2\pi[(1+g_m r_o)C_\mu+C_\pi]}\right|\ Hz}$ #1

-10

訂正在 P.3

2.




$\boxed{|A_1|}$: ($C_E$ 為開路)

$\left|\frac{V_o}{V_i}\right| = \left|\frac{\cancel{r_\pi+(1+\beta)R_E}}{R_s+r_\pi+(1+\beta)R_E}\cdot\frac{1}{\cancel{r_\pi+(1+\beta)R_E}}\cdot\beta(-R_C)\right| = \boxed{\left|\frac{-\beta R_C}{R_s+r_\pi+(1+\beta)R_E}\right|\ V/V}$ #2

$\boxed{|A_2|}$: $C_E$ 為短路:

$\left|\frac{V_o}{V_i}\right| = \left|\frac{\cancel{r_\pi}}{R_s+r_\pi}\cdot\frac{1}{\cancel{r_\pi}}\cdot\beta\cdot(-R_C)\right| = \boxed{\left|\frac{-\beta R_C}{R_s+r_\pi}\right|\ V/V}$ #2

$|f_1|$: 當電晶體E極等效為開路:

$|R_E| = \frac{1}{2\pi|f_1|\cdot C_E}$ ⇒ $2\pi|f_1| = \frac{1}{R_E C_E}$ ⇒ $\boxed{|f_1| = \frac{1}{2\pi R_E C_E}\ Hz}$ #2

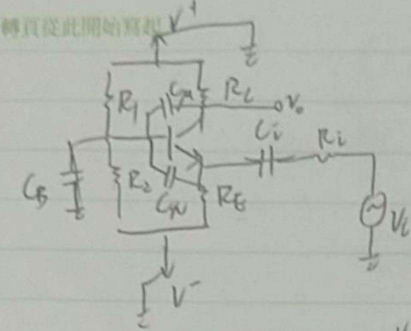
$|f_2|$: $C_E$ 被短路的頻率:

$|f_2| = \frac{1}{2\pi\tau}$

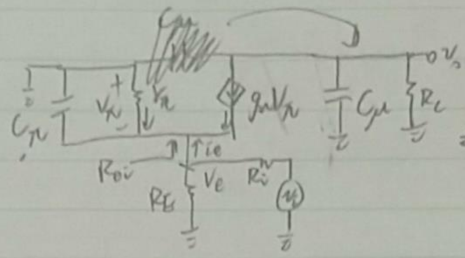
$\tau = C_E(R_o) = C_E\left(R_E // \frac{r_\pi+R_s}{1+\beta}\right)$

⇒ $\boxed{|f_2| = \frac{1}{2\pi C_E\left(R_E // \left(\frac{r_\pi+R_s}{1+\beta}\right)\right)}\ Hz}$ #2

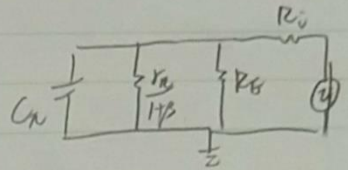
3.



$\Rightarrow$



$\Rightarrow$

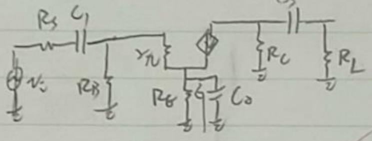


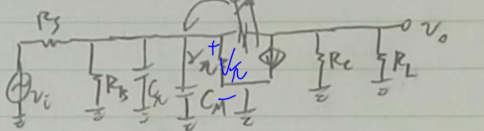
$$i_e + \frac{v_\pi}{r_\pi} + g_m v_\pi + \frac{v_\pi}{\frac{1}{sC_\pi}} = 0 \quad (v_\pi = -v_e) \Rightarrow \frac{-i_e}{-v_e} = \frac{1}{r_\pi} + g_m + sC_\pi \Rightarrow \frac{v_e}{i_e} = \frac{1}{\frac{1}{r_\pi} + g_m + sC_\pi} = \frac{r_\pi}{1+\beta} + \frac{1}{sC_\pi}$$

$$\Rightarrow \boxed{f_{H\pi}} = \frac{1}{2\pi \tau_{p\pi}} = \boxed{\frac{1}{2\pi C_\pi\left(\frac{r_\pi}{1+\beta} // R_E // R_i\right)} \text{ Hz}} \quad \#3$$

$$\boxed{f_{H\mu}} = \frac{1}{2\pi \tau_{p\mu}} = \boxed{\frac{1}{2\pi C_\mu R_C} \text{ Hz}} \quad \#3$$

4.





求 $\tau_1$： $C_2$、$C_3$ 短路

$\tau_1 = C_1(R_S + R_B // r_\pi)$

求 $\tau_2$： $C_1$、$C_3$ 短路

$\tau_2 = C_2\left(R_E // \left(\frac{r_\pi + R_B // R_S}{1+\beta}\right)\right)$

求 $\tau_3$： $C_1$、$C_2$ 短路

$\tau_3 = C_3(R_C + R_L)$

$$\tau_p = (R_S // R_B // r_\pi)\left(C_\pi + (1+|A_v|)C_\mu\right)$$

~~$|A_v| = \frac{R_B // r_\pi}{R_S + R_B // r_\pi} \cdot \frac{1}{r_\pi} \cdot \beta \cdot R_C // R_L$~~

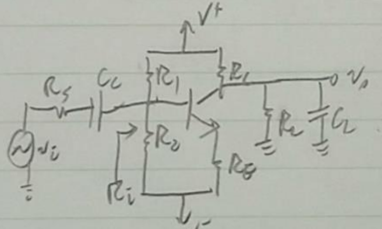
$|A_v| = \left|\frac{V_o}{V_\pi}\right| = \frac{1}{r_\pi} \cdot \beta \cdot R_C // R_L$

$$\Rightarrow \boxed{\omega_H} = \frac{1}{\tau_p} = \boxed{\frac{1}{(R_S // R_B // r_\pi)\left[C_\pi + \left(1 + \left(\cancel{\frac{R_B // r_\pi}{R_S + R_B // r_\pi}} \cdot \frac{1}{r_\pi} \cdot \beta \cdot R_C // R_L\right)\right)C_\mu\right]} \text{ rad/s}} \quad \#4$$

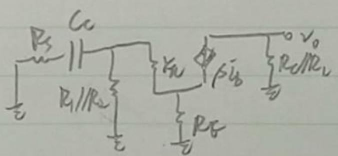
$-5$

$$\Rightarrow \boxed{\omega_L} = \frac{1}{\tau_1} + \frac{1}{\tau_2} + \frac{1}{\tau_3} = \boxed{\frac{1}{C_1(R_S + R_B // r_\pi)} + \frac{1}{C_2\left(R_E // \left(\frac{r_\pi + R_B // R_S}{1+\beta}\right)\right)} + \frac{1}{C_3(R_C + R_L)} \text{ rad/s}} \quad \#4$$

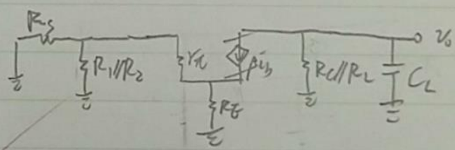
5.



$\Rightarrow$



$\Rightarrow$



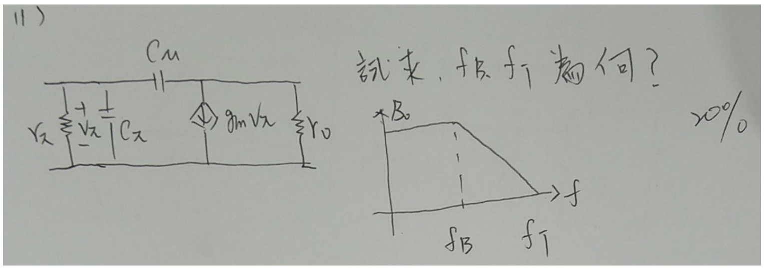
$$\boxed{|A_v|} = \frac{R_i}{R_S + R_i} \cdot \frac{1}{r_\pi + (1+\beta)R_E} \cdot \beta \cdot R_C // R_L$$

$$R_i = R_1 // R_2 // (r_\pi + (1+\beta)R_E)$$

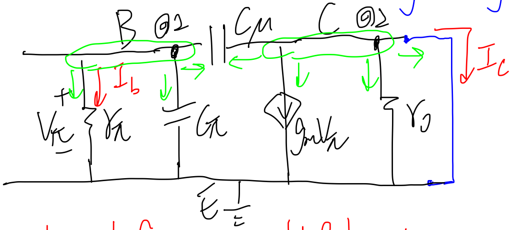
$$= \boxed{\frac{R_1 // R_2 // (r_\pi + (1+\beta)R_E)}{R_S + R_1 // R_2 // (r_\pi + (1+\beta)R_E)} \cdot \frac{\beta \cdot R_C // R_L}{r_\pi + (1+\beta)R_E} \text{ V/V}} \quad \#5$$

$$\boxed{f_L = \frac{1}{2\pi C_C\{R_S + [R_1 // R_2 // ((1+\beta)R_E + r_\pi)]\}} \text{ Hz}} \quad \#5$$

$$\boxed{f_H = \frac{1}{2\pi C_L(R_C // R_L)} \text{ Hz}} \quad \#5$$




Connect the collector to the signal ground to determine the high frequency effect to the BJT:




By the definition, $|h_{fe}| = 1$ at $f = f_T$.

$$h_{fe} = \frac{I_c}{I_b}$$

By KCL:

@1: $$I_b + \frac{V_\pi}{\frac{1}{sC_\pi}} + \frac{V_\pi}{\frac{1}{sC_\mu}} = 0 \Rightarrow I_b = -V_\pi(sC_\pi + sC_\mu)$$

@2: $$-\frac{V_\pi}{\frac{1}{sC_\mu}} + g_m V_\pi + I_c = 0 \Rightarrow I_c = V_\pi(sC_\mu - g_m)$$

$$= -\frac{sC_\mu - g_m}{sC_\pi + sC_\mu} = -\frac{C_\mu}{C_\pi + C_\mu} + \frac{g_m}{\underset{\underset{j\omega = j2\pi f}{\Uparrow}}{s}(C_\pi + C_\mu)}$$

$$\Rightarrow |h_{fe}| = \sqrt{\underbrace{\left(-\frac{C_\mu}{C_\pi + C_\mu}\right)^2}_{\substack{C_\mu \ll C_\pi \\ A \ll 1}} + \underbrace{\left(\frac{\overset{mS}{g_m}}{2\pi \underset{MHz}{f} \cdot (\underset{pF}{C_\pi + C_\mu})}\right)^2}_{B \approx \left(\frac{10^{-3}}{10^{-6}}\right)^2 \gg 1}} \approx \frac{g_m}{2\pi f (C_\pi + C_\mu)}$$

$\Rightarrow$ When $|h_{fe}| = 1$, $f = f_T$:

$$|h_{fe}| = 1 = \frac{g_m}{2\pi f_T (C_\pi + C_\mu)} \Rightarrow \boxed{f_T = \frac{g_m}{2\pi (C_\pi + C_\mu)}} \#1$$