MODEL ANSWER

Name:____________________________________

Matric No:_______________Section:_____

الجامعة الإسلامية العالمية ماليزيا

# INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

## MID-TERM EXAMINATION
## SEMESTER II, 2013/2014 SESSION
## KULLIYYAH OF ENGINEERING

| | | | |
|---|---|---|---|
| Programme | : ENGINEERING | Level of Study | : UG 2 |
| Time | : 8:00 pm-10:00 pm | Date | : 20/03/2014 |
| Duration | : 2 Hours | | |
| Course Code | : ECE 2133 | Section(s) | : 1 & 2 |
| Course Title | : **Electronic Circuits** | | |

This Question Paper consists of **Eight (8)** Printed Pages (Including Cover and a blank page) with **Three (3)** Questions.

***INSTRUCTION(S) TO CANDIDATES***

DO NOT OPEN UNTIL YOU ARE ASKED TO DO SO

- **Use only pen for writing answer.**
- **Do not use your own sheet.**
- A total mark of this examination is **60**.
- This examination is worth **30%** of the total assessment.
- For drawing you may use pencil
- Answer **ALL THREE(3)** questions.
- **Answer on the question paper.**

**Any form of cheating or attempt to cheat is a serious offence which may lead to dismissal.**

| | Question 1 | | Question 2 | | Question 3 | | Total Marks |
|---|---|---|---|---|---|---|---|
| Marks | 20 | | 20 | | 20 | | 60 |
| Marks Obtained | | | | | | | |

**Q.1 [20 marks]**

(a) Consider the circuit shown in **Fig. 1(a)**, derive the expression (step by step) for the voltage transfer function $T(s) = {v_o(s)}/{v_i(s)}$ and find the time constant and the corner frequency. **(8 marks)**

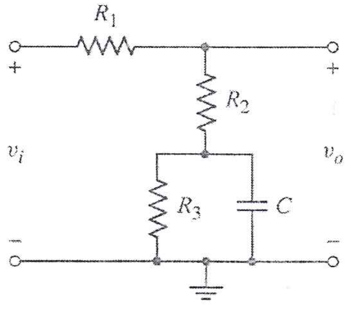



**Fig. 1(a)**

$$R_3 \| \frac{1}{sC} = \frac{R_3\left(\frac{1}{sC}\right)}{R_3 + \frac{1}{sC}} = \frac{R_3}{1+sR_3C}$$

$$T(s) = \frac{V_o(s)}{V_i(s)} = \frac{R_2 + \frac{R_3}{1+sR_3C}}{R_1 + R_2 + \frac{R_3}{1+sR_3C}}$$

$$= \frac{R_2 + R_3 + sR_2R_3C}{R_1+R_2+R_3 + s(R_1+R_2)R_3C}$$

$$= \frac{R_2+R_3}{R_1+R_2+R_3} \cdot \frac{\left[1 + \frac{sR_2R_3C}{(R_2+R_3)}\right]}{\left[1 + \frac{s(R_1+R_2)R_3C}{(R_1+R_2)+R_3}\right]}$$

$$= K \cdot \frac{1+s\tau_A}{1+s\tau_B}$$

$$\tau_A = \frac{R_2R_3}{R_2+R_3}C = (R_2 \| R_3)C$$

$$\therefore f_A = \frac{1}{2\pi\tau_A}$$

$$\tau_B = \frac{(R_1+R_2)R_3}{(R_1+R_2)+R_3} \cdot C = (R_1+R_2)\| R_3 \cdot C$$

$$\therefore f_B = \frac{1}{2\pi\tau_B}$$

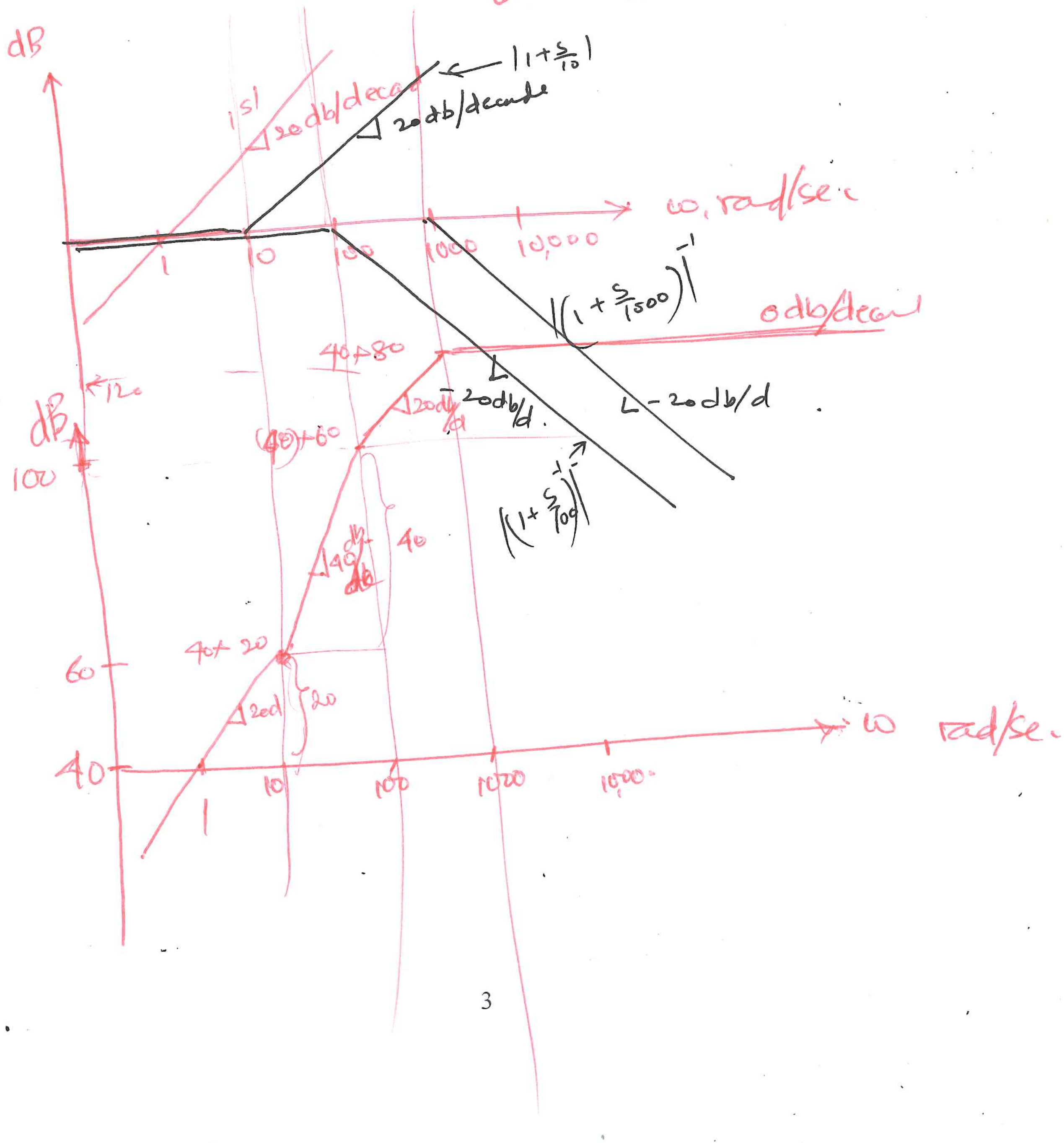
**(b)** Draw the Bode plot (magnitude and phase) of the following transfer function.

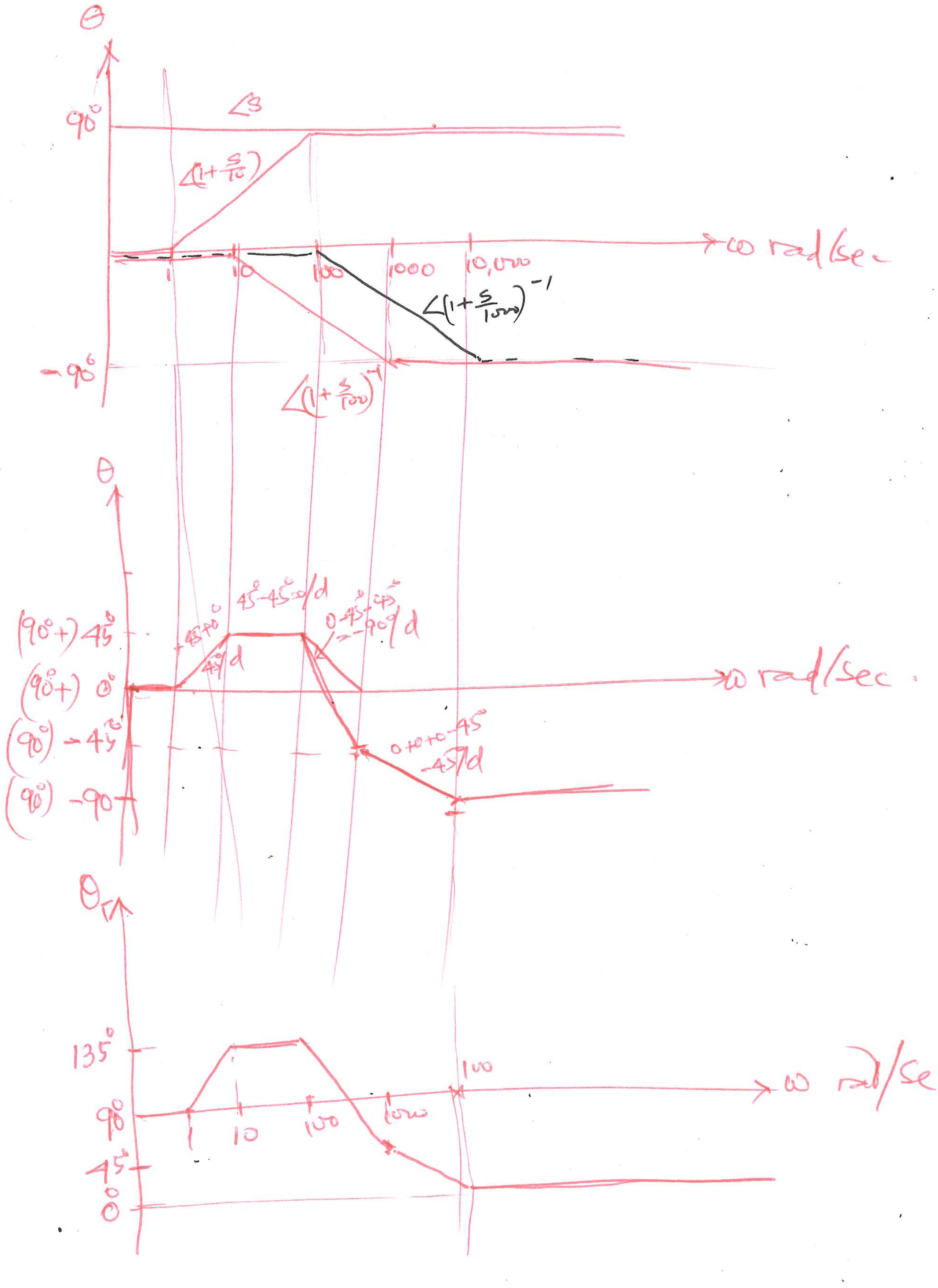
. **(12 marks)**

$$T(s) = \frac{10^6 s(s+10)}{(s+100)(s+1000)}$$

$$= \frac{10^6 \cdot s \times 10 \left[1 + \frac{s}{10}\right]}{100\left[1+\frac{s}{100}\right] 1000 \left[1 + \frac{s}{1000}\right]}$$

$$= \frac{100 \; s \cdot \left[1 + \frac{s}{10}\right]}{\left[1+\frac{s}{100}\right]\left[1 + \frac{s}{1000}\right]}$$



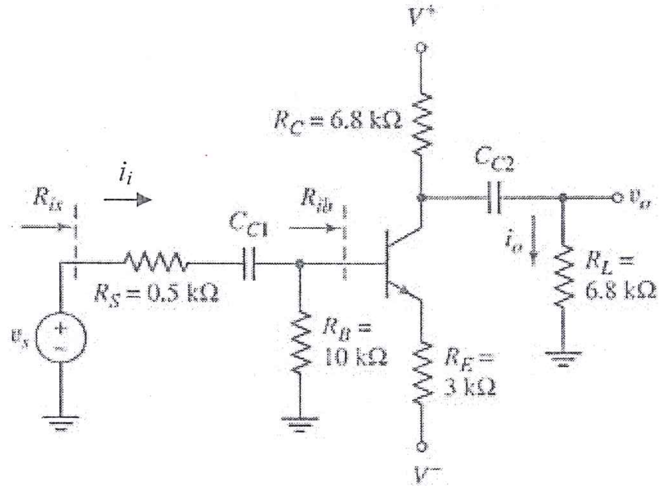

θ
90°
∠s
∠(1+ s/10)
ω rad/sec
1
10
100
1000
10,000
∠(1+ s/1000)^-1
-90°
∠(1+ s/100)^-1
θ
(90°+) 45°
(90°+) 0°
(90°) -45°
(90°) -90
ω rad/sec
45°-45°=0/d
0-45°-45°
=-90°/d
0+0+0-45°
-45°/d
θ
135°
90°
45°
0°
1
10
100
1000
ω rad/Se

**Q.2 [20 marks]**

(a) Draw the small signal equivalent circuit diagram of the circuit shown in **Fig. 2(a)** and find the followings: **(10 marks)**

Find the small signal midband voltage gain $A_v = \frac{v_o}{v_s}$ and the lower corner frequency due to $C_{C1}$ assuming that $C_{C2} = \infty$.

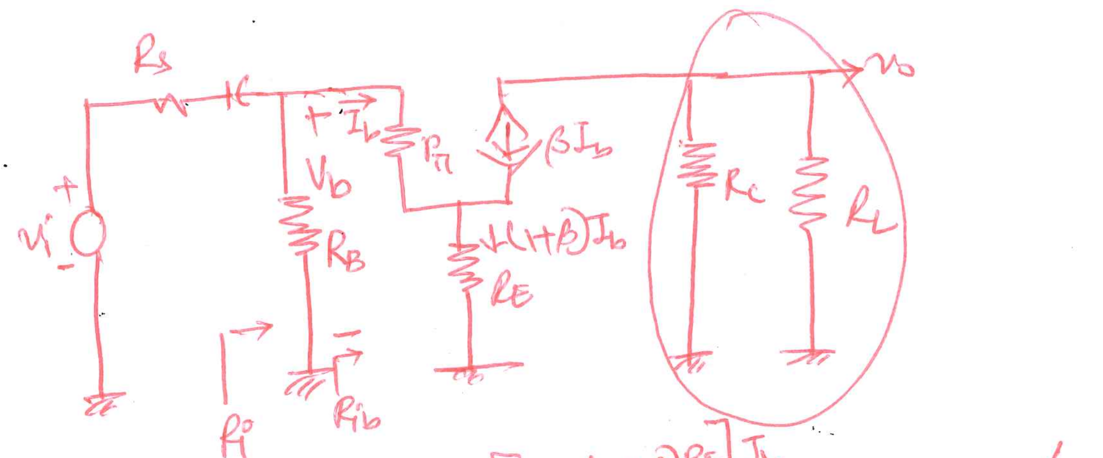
~~Given that $R_s = 0.5$ kΩ, $R_1 = 330$ kΩ, $R_2 = 85$ kΩ, $R_C = 4$ kΩ, $R_E = 1.5$ kΩ,~~ $C_{C1} = 1$ μF and $C_{C2} = \infty$. The transistor has small-signal hybrid-π parameters, $r_\pi = 3$ kΩ, $g_m = 40$mA/V and $r_o = \infty$.




$\beta = g_m r_\pi$
$= 40 \times 3 = 120$

**Fig. 2(a)**

$R_L' = R_C || R_L$




$V_b = r_\pi I_b + (1+\beta) I_b R_E = [r_\pi + (1+\beta)R_E] I_b$

$V_o = -\beta I_b R_L'$

$R_{ib} = \frac{V_b}{I_b} = r_\pi + (1+\beta)R_E$

$= 3 + (1+120)3$

$= 366$ K.

$R_L' = 6.8 || 6.8 = 3.4$ K

$A_{VA} = \frac{V_o}{V_b} = \frac{-\beta I_b R_L'}{(r_\pi + (1+\beta)R_E) I_b}$

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

$= -\frac{120 \times 3.4}{366} = -1.1147$

$R_i = R_{ib} \| R_B$

$= 366 \| 10 = 9.73K$

$\therefore A_v = A_{vA} \frac{R_i}{R_i + R_s} = -1.1147 \times \frac{9.73}{9.73 + 0.5}$

$= -1.06 \ V/V$ ←

$\tau = (R_s + R_i) C_{C1} = (0.5 + 9.73)k \cdot 1u$

$= 10.23 \ ms$

$\therefore f_L = \frac{1}{2\pi\tau} = 15.55 \ Hz$ ←

(b) Draw the small signal equivalent circuit diagram of the circuit shown in Fig. 2(b) and find the followings: **(10 marks)**

(i) the midband voltage gain $A_v = \frac{v_o}{v_i}$,

(ii) the output resistance $R_o$ of the amplifier, and

(iii) the corner frequency due to $C_L = 4$ pF assumed that $C_C \to \infty$.

Given that $R_{si} = 1$ kΩ, $R_1 = 180$ kΩ, $R_2 = 330$ kΩ, $R_s = 3.0$ kΩ, $R_L = 6$ KΩ. The transistor parameters are $g_m$=0.65 mA/V and $r_o = 100$ kΩ.

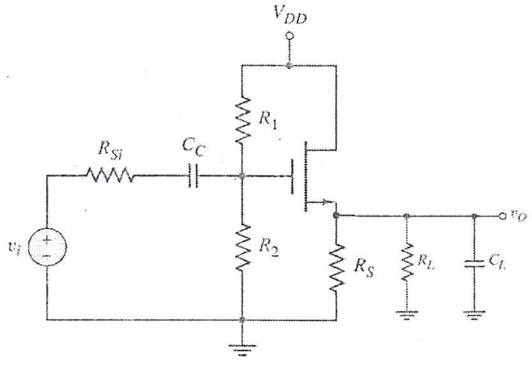
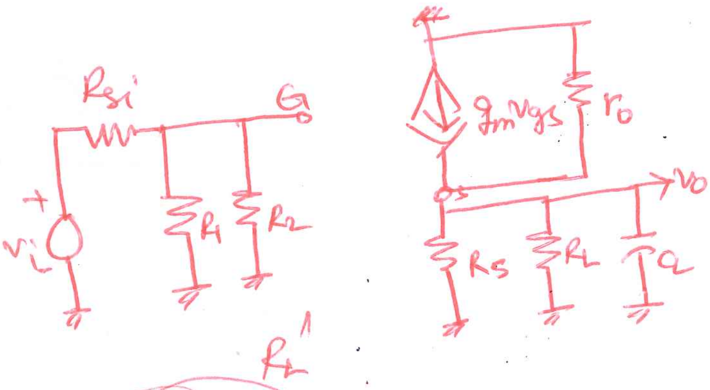
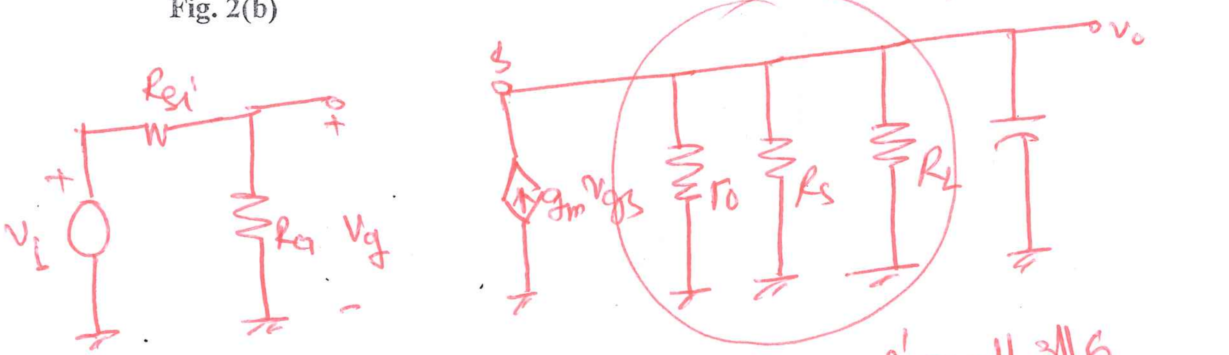



**Fig. 2(b)**




$R_L' = 100 \| 3 \| 6$
$= 1.961\,k\Omega$

(i) Midband gain

$v_o = g_m v_{gs} R_L'$

$v_g = v_{gs} + g_m v_{gs} R_L'$
$= v_{gs}(1 + g_m R_L')$

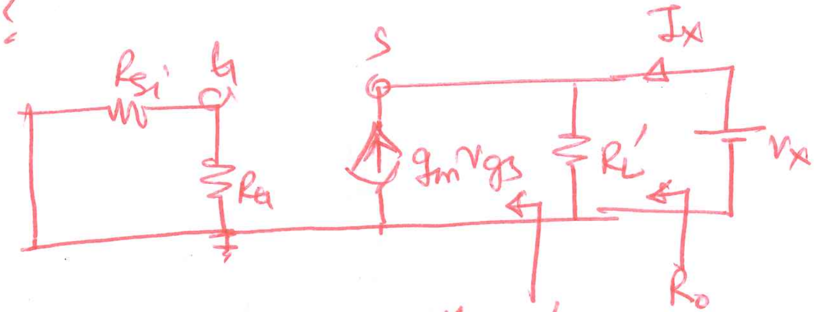
$A_v = \frac{v_o}{v_g} = \frac{g_m R_L'}{1 + g_m R_L'} = \frac{0.65 \times 1.961}{1 + 0.65 \times 1.961} = 0.560$ V/V

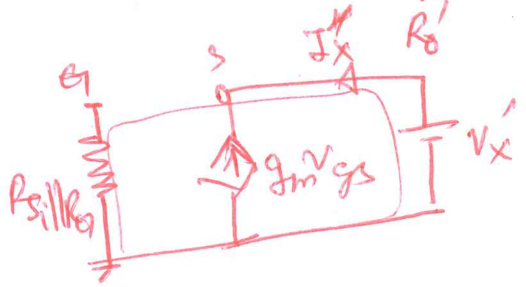
$R_i = R_G = R_1 \| R_2 = 180 \| 330 = 116.47K$

$$A_V = A_{V_A} \times \frac{R_i}{R_{si} + R_i} = 0.56 \times \frac{116.47}{1 + 116.47}$$

$$= 0.555 \text{ V/V}$$

ii) $R_o' = ?$




$I_x' = -g_m v_{gs}$

$v_{gs} + v_x' = 0$

$\therefore v_x' = -v_{gs}$

$\therefore I_x' = g_m v_x'$ $\quad \therefore R_o' = \frac{v_x'}{I_x'} = \frac{1}{g_m}$

$\therefore R_o = R_o' \| R_L' = \left(\frac{1}{0.65}\right) \| 1.961 = 862.11\ \Omega$

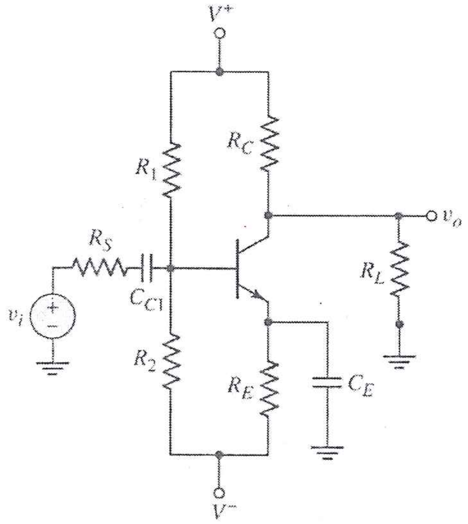
(iii) $\tau = C_L \times R_o = 4p \times 862.11 = 3.448\ ns$

$\therefore f_H = \frac{1}{2\pi\tau} = 46.15\ MHz$

(b) The common emitter amplifier is shown in Fig. 3(b) and operated at high frequencies. Draw the simplified high-frequency small signal equivalent circuit diagram and

(i) find the Miller capacitance, and

(ii) determine the upper 3dB frequency ($f_H$) considering Miller capacitance and without considering Miller capacitance. **(10 marks)**




The circuit parameters are:

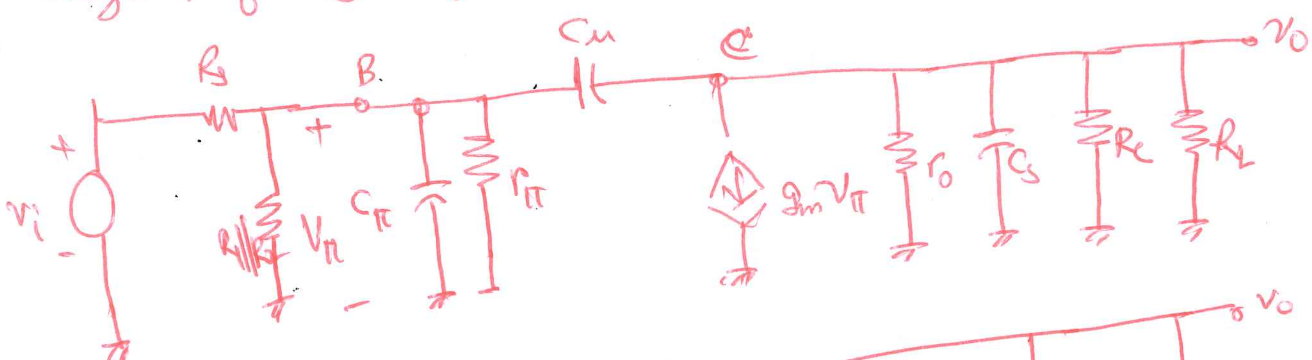
$R_s$=1kΩ, $R_1$= 120kΩ, $R_2$= 20 kΩ, $R_E$ = 2 kΩ, $R_C$ = 5 kΩ, $R_L$ = 20 kΩ, $C_{C1}$ =∞ and $C_E$= ∞ .

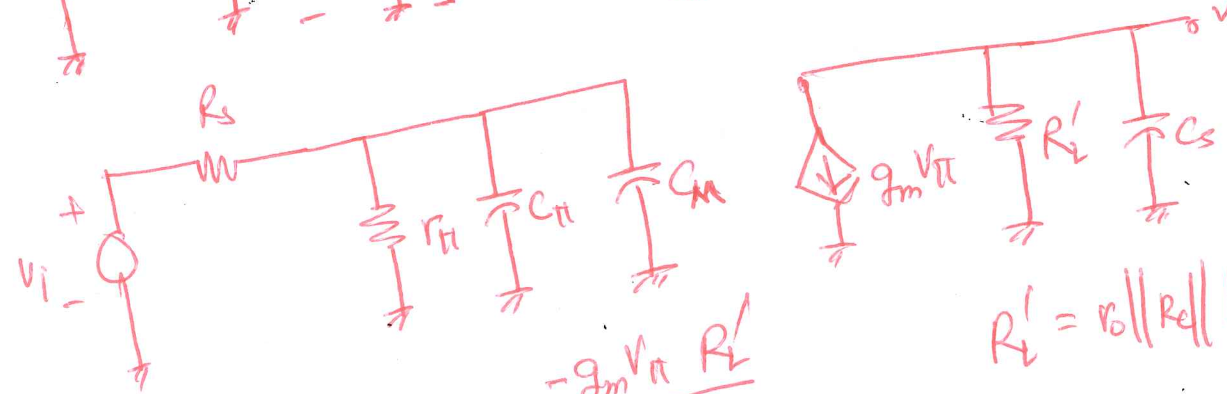
The transistor parameters are :

$r_\pi$ = 3 kΩ, $g_m$= 40 mA/V and $r_o$ = 100 kΩ, $C_\pi$ = 25 pF, and $C_\mu$= 4 pF

**Fig. 3(b)**

* High frequency equivalent circuit diagram




$R_L' = r_o \| R_C \| R_L$

$$A_{VA} = \frac{V_o}{V_\pi} = \frac{-g_m V_\pi R_L'}{V_\pi}$$

$$= -g_m R_L'$$

$$= -40 \times (100 \| 5 \| 20) = -153.846$$

i) $C_M = C_\mu [1 - A_v]$

$= 4p [1 + 153.846] k = 619.384 pF$

$R_{eq} = (R_s || R_1 || R_2 || r_\pi)$

ii) $\tau_{wo} = C_{eq} R_{eq}$

$= 1 || 120 || 20 || 3$

$= 718.563 \Omega$

<u>with Miller capacitance</u>

$C_T = C_\pi + C_M$

$= 25p + 619.384p$

$= 644.384p$

$\tau_M = 463.03 nS$

$f_{H_M} = \frac{1}{2\pi \tau_M} = 343.724$ KHZ ←

<u>with out Miller capacitance</u>

$C_T = C_\pi = 25P$

$\therefore \tau_{wo} = 17.96 nS$

$\therefore f_{H_{wo}} = 8.859$ MHZ ←

**Q.3 [20 marks]**

(a) Draw the simplified high frequency small-signal equivalent circuit diagram of the ac circuit shown in **Fig. 3(a)** and derive step by step short circuit current gain $A_i = I_g/I_d$. Then find cutoff frequency $f_T$. **(10 marks)**

$I_d$ $I_g$

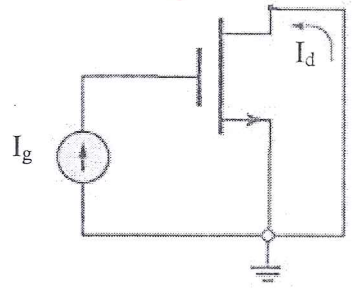
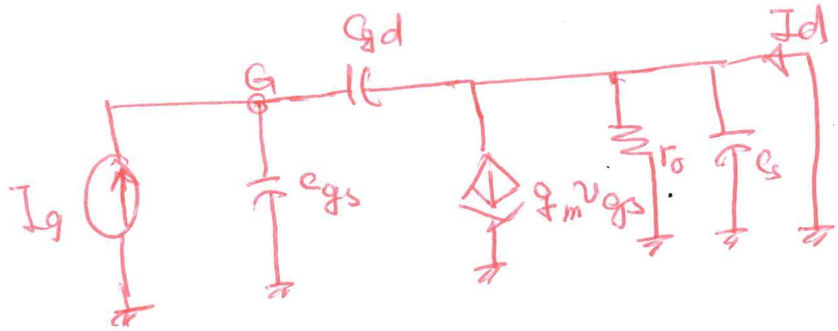
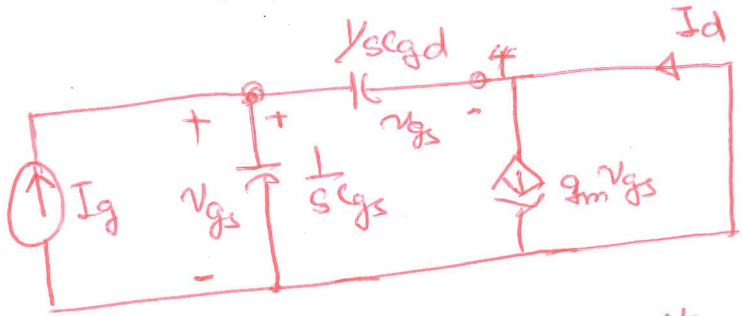



**Fig. 3(a)**




$$I_d = g_m v_{gs} - \frac{v_{gs}}{1/sC_{gd}} = v_{gs}\left[g_m - sC_{gd}\right]$$

$$I_g = \frac{v_{gs}}{1/sC_{gs}} + \frac{v_{gs}}{1/sC_{gd}} = v_{gs}\left[sC_{gs} + sC_{gd}\right]$$

$$\therefore A_i = \frac{I_d}{I_g} = \frac{g_m - sC_{gd}}{s(C_{gs}+C_{gd})} \simeq \frac{g_m}{s(C_{gs}+C_{gd})}$$

considering ($g_m \gg sC_{gd}$)

($s = j\omega$)

$$|A_i| = \left|\frac{g_m}{s(C_{gs}+C_{gd})}\right| = \frac{g_m}{\omega(C_{gs}+C_{gd})}$$

For cut of freq $|A_i| = 1 = \dfrac{g_m}{\omega_T(C_{gs}+C_{gd})}$

$$\therefore \omega_T = \frac{g_m}{(C_{gs}+C_{gd})} \text{ rad/sec} \qquad f_T = \frac{g_m}{2\pi(C_{gs}+C_{gd})}$$