Name:______________________________

Matric No:______________Section:_____

الجامعة الإسلامية العالمية ماليزيا

# INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

## MID-TERM EXAMINATION
## SEMESTER I, 2012/2013 SESSION
## KULLIYYAH OF ENGINEERING

Programme : ENGINEERING Level of Study : UG 2

Time : 8:00pm-10:00 pm Date : 19/10/2012

Duration : 2 Hours

Course Code : ECE 2133 Section(s) : 1 & 2

Course Title : **Electronic Circuits**

This Question Paper consists of **Nine (9)** 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.**
- **Useful formulas are given in page 9.**
- 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.

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) Determine the Q-point values ($I_{DQ}$ and $V_{DSQ}$) for the circuit shown in **Fig. 1(a)**. The transistor parameters are $V_{TN} = 0.8$ V, $K_n = 2\text{mA/V}^2$ and $\lambda = 0$. The circuit parameters are $V_{DD} = 12$ V, $R_s = 1$ kΩ, $R_1 = 225$ kΩ, $R_2 = 175$ kΩ, $R_D = 2$ kΩ and $R_L = 10$ kΩ, $C_{C1} = C_{C2} = 10$ μF. Also calculate small signal circuit parameters.

**(10 marks)**

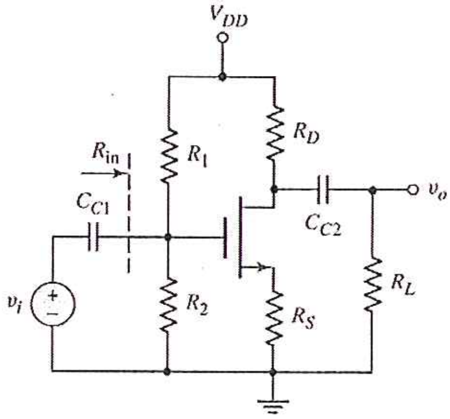
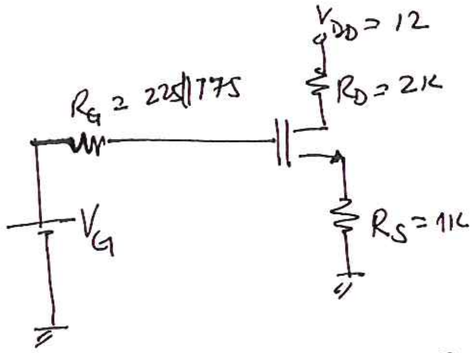



**Fig. 1(a)**




$R_G = R_1 \| R_2 = 225 \| 175 = 98.4375\ k\Omega$

$V_G = \frac{12 \times 175}{225+175} = 5.25\ V$ ←

KVL: $V_G = I_G R_G + V_{GS} + I_D R_S$ ($I_G = 0$)  $[\because I_D = K_n (V_{GS} - V_T)^2]$ considering sat$^n$.

$= V_{GS} + I_D R_S = V_{GS} + K_n (V_{GS} - V_T)^2 R_S$

$\therefore 5.25 = V_{GS} + 2(V_{GS} - 0.8)^2 \times 1 = V_{GS} + 2V_{GS}^2 - 2\times2\times0.8 V_{GS} + 2\times0.64$

$\Rightarrow 2V_{GS}^2 - 2.2 V_{GS} - 3.97 = 0$   $\therefore V_{GS_1} = 2.062\ V$, $V_{GS_2} = -0.96\ V$

Considering $V_{GSQ} = 2.062\ V > V_T$

$\therefore I_{DQ} = K_n (V_{GSQ} - V_T)^2 = 2(2.062 - 0.8)^2 = 3.185\ mA$ ←

$V_{DSQ} = V_{DD} - I_D (R_D + R_S) = 12 - 3.185(2+1) = 2.444\ V$ ←

$g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{2 \times 3.185} = 5.05\ mA/V$

$r_o = \frac{1}{\lambda I_{DQ}} = \infty$ ←

$V_{DS} = 2.444\ V$

$V_{GS} - V_T = 2.062 - 0.8$

$V_{DS} > V_{GS} - V_T$

Saturation region

(b) For the circuit shown in **Fig 1(b)**, design a bias stable circuit such that $I_{CQ} = 0.8$ mA and $V_{CEQ} = 1.0$ V assuming $\beta=120$ and $V_A = 100$ and hence find small signal parameters $g_m$, $r_\pi$ and $r_o$. **(10 marks)**

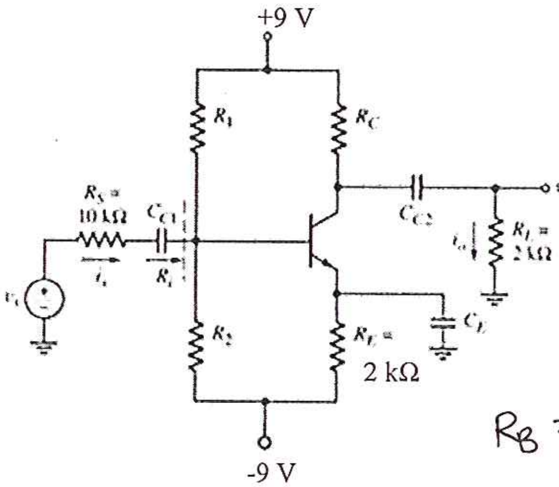
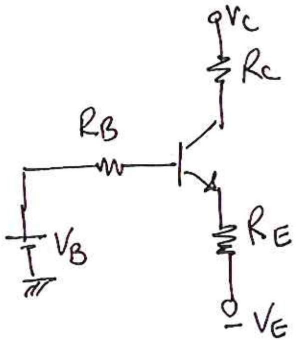



**Fig. 1 (b)**




$R_B = 0.1(1+\beta) R_E$ for stable bias

$= 0.1 \times 121 \times 2 = 24.2 K\Omega$

KVL

$V_C = I_C R_C + V_{CE} + I_E R_E - V_E$

$V_C + V_E - V_{CE} = I_C R_C + I_E R_E = I_C R_C + \frac{(1+\beta)}{\beta} I_C R_E$

$\therefore I_C R_C = (V_C + V_E - V_{CE}) - \frac{(1+\beta)}{\beta} I_C R_E$

$= (9+9-1) - \frac{121}{120} \times 0.8 \times 2 = 15.3867$ V

$\therefore R_C = \frac{15.3867}{0.8} = 19.233 K$

KVL

$V_B = I_B R_B + V_{BE} + I_E R_E - V_E = \frac{I_C}{\beta} R_B + V_{BE} + \frac{(1+\beta)}{\beta} I_C R_E - V_E$

$= \frac{0.8}{120} \times 24.2 + 0.7 + \frac{121}{120} \times 0.8 \times 2 - 9 = -6.525$ V

again, $V_B = \frac{(V_{CC} + V_E) R_2}{R_1 + R_2} - V_E = \frac{R_B}{R_1}(V_{CC} + V_E) - V_E$

$-6.525 = \frac{24.2}{R_1}(9+9) - 9 \Rightarrow R_1 = 176.26 K\Omega$

$\frac{1}{R_B} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R_2 = 28.05 K\Omega$

$g_m = \frac{I_{CQ}}{V_T} = \frac{0.8m}{0.026} = 30.77 mA/V$

$r_\pi = \frac{\beta}{g_m} = \frac{120}{30.77} = 3.9 K\Omega$

$r_o = \frac{V_A}{I_{CQ}} = 125 K\Omega$

**Q.2 [20 marks]**

(a) Draw the small signal equivalent circuit diagram of the circuit shown in **Fig. 2(a)** and find the input resistance $R_i$ and the voltage gain $A_v = \frac{v_o}{v_s}$ of the amplifier. Given that $R_s$=0.5 kΩ, $R_1$=330 kΩ, $R_2$=85 kΩ, $R_C$ = 4 kΩ, $R_E$=1.5 kΩ, and $I_{CQ}$ = 0.4 mA. Transistor parameters are β=100 and $V_A = \infty$. **(10 marks)**

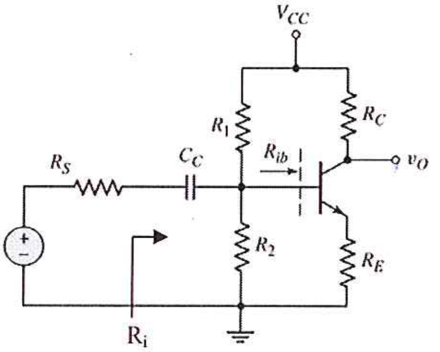
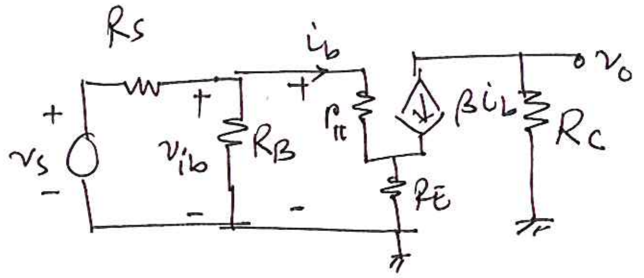



**Fig. 2(a)**




$v_o = -\beta i_b R_c$

$v_{ib} = r_\pi i_b + (1+\beta) i_b R_E$

$= \left[r_\pi + (1+\beta) R_E\right] i_b$

$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{100 \times 0.026}{0.4}$

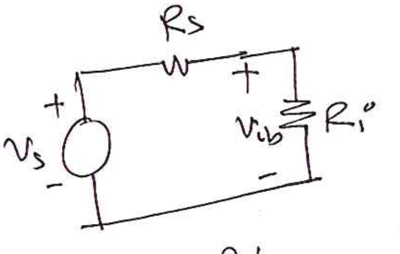
$= 6.5\,K\Omega$

$\therefore R_{ib} = \frac{v_{ib}}{i_b} = r_\pi + (1+\beta) R_E$

$= 6.5 + (1+100) \times 1.5 = 158\,K\Omega$ ←

$R_i = R_1 \| R_2 \| R_{ib} = 330 \| 85 \| 158$

$= 47.34\,K\Omega$




$v_o = -\frac{\beta R_c v_{ib}}{R_{ib}}$

$\therefore A_{vA} = \frac{v_o}{v_{ib}} = -\frac{\beta R_c}{R_{ib}}$

$= -\frac{100 \times 4}{158} = -2.5316$

$\frac{v_{ib}}{v_s} = \frac{R_i}{R_s + R_i} = \frac{47.34}{0.5 + 47.34} = 0.989$

$\therefore A_v = \frac{v_o}{v_s} = A_{vA} \times \frac{v_{ib}}{v_s}$

$= A_{vA} \times \frac{R_i}{R_s + R_i} = -2.504$ ←

(b) Draw the small signal equivalent circuit diagram of the circuit shown in **Fig. 2(b)** and find the voltage gain $A_v = \frac{v_o}{v_i}$ and output resistance $R_o$ of the amplifier. Given that $R_{si} = 2$ kΩ, $R_1 = 180$ kΩ, $R_2 = 330$ kΩ, $R_s = 1.0$ kΩ and $I_D = 6$ mA. The transistor parameters are $V_{TN} = 1.5$ V, $K_n = 4$ mA/V$^2$ and $\lambda = 0.01$ V$^{-1}$. **(10 marks)**

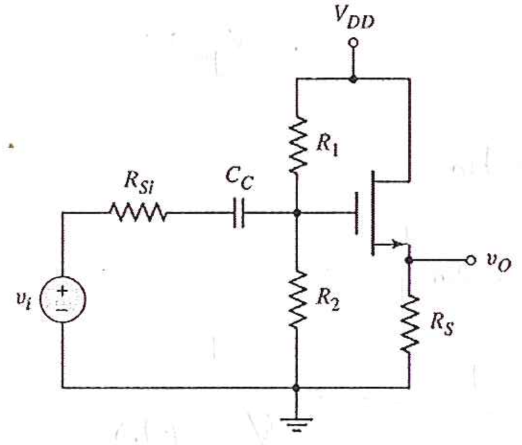
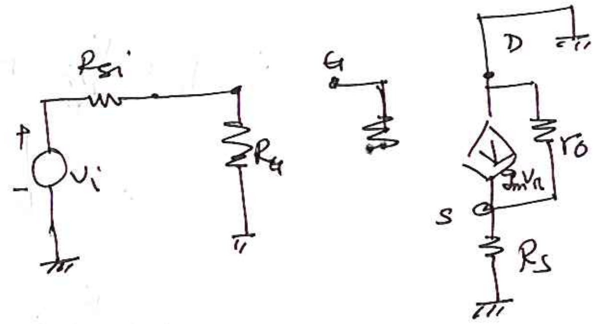
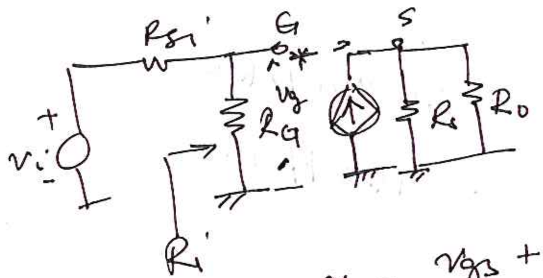



**Fig. 2(b)**




$R_L' = R_o \| R_s =$

$v_o = g_m v_{gs} R_L'$

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

$\therefore v_{gs} = \frac{v_g}{1 + g_m R_L'}$

$A_{vA} = \frac{v_o}{v_g} = \frac{g_m R_L'}{1 + g_m R_L'}$

$\therefore v_o = g_m v_{gs} R_L'$

$= \frac{g_m R_L'}{1 + g_m R_L'} v_g$

$R_i = R_G$

$R_G = R_1 \| R_2 = 180 \| 330 = 116.47$ kΩ

$A_v = \frac{v_o}{v_i} = A_{vA} \times \frac{R_i}{R_i + R_{si}}$

$\therefore = \frac{g_m R_L'}{1 + g_m R_L'} \times \frac{R_G}{R_G + R_{si}}$

$g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{4 \times 6} = 9.79 \simeq 9.8$ mA/V

$r_o = \frac{1}{\lambda I_{DQ}} = \frac{1}{0.01 \times 6} = 16.67$ kΩ

$\therefore R_L' = r_o \| R_s = 0.943$ kΩ

$\therefore g_m R_L' = 9.245$

$= \frac{9.245}{1 + 9.245} \times \frac{116.47}{116.47 + 2}$

$= 0.902 \times 0.983 = 0.887$

**Q.3 [20 marks]**

(a) Draw the small signal equivalent circuit diagram of the circuit shown in **Fig. 3(a).**

**(6 marks)**

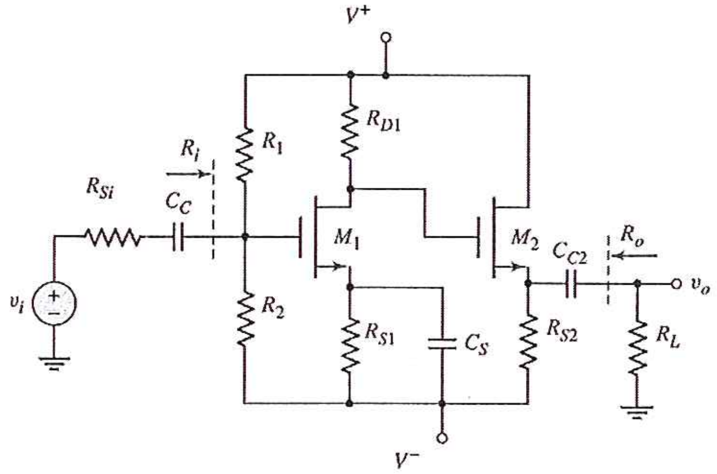
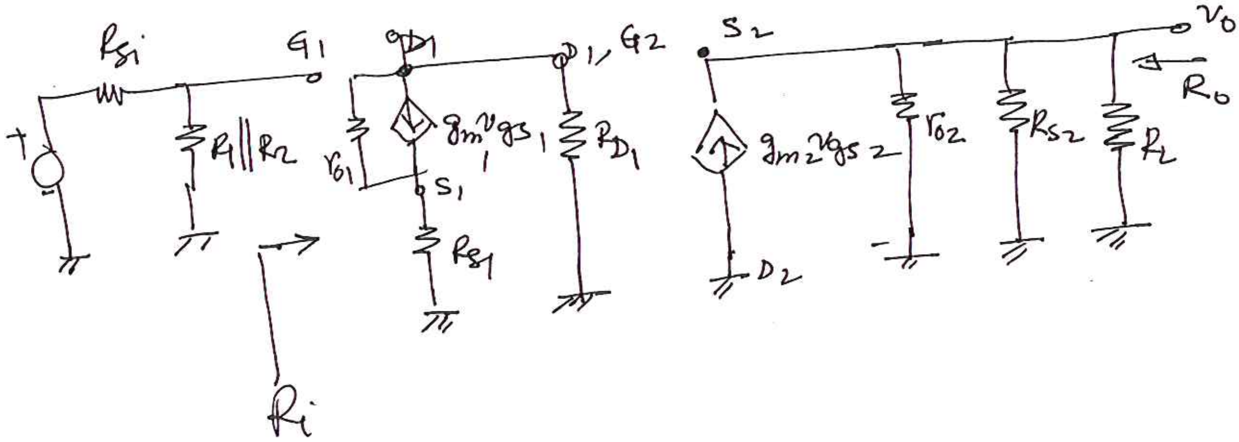
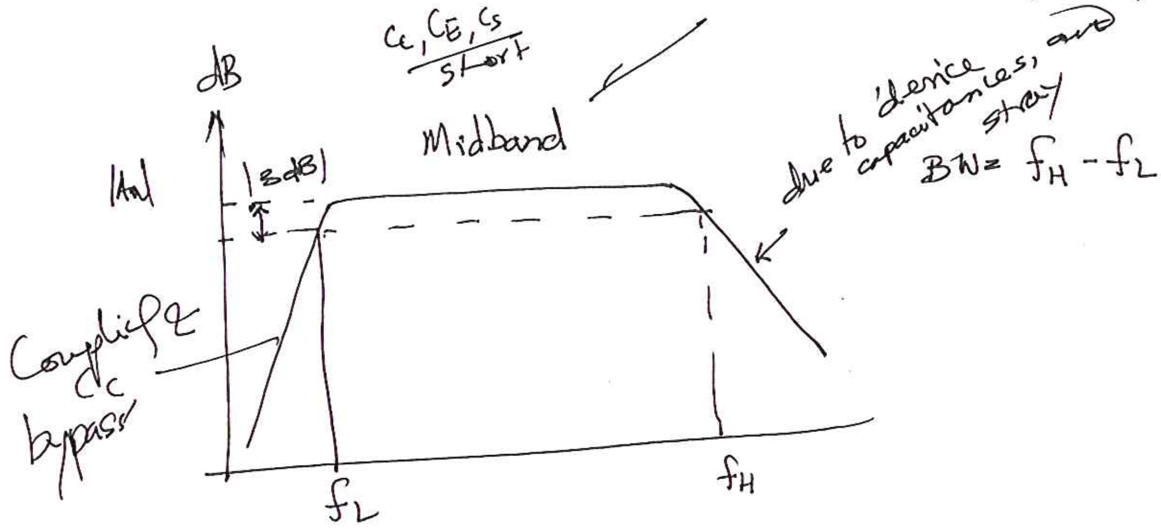



**Fig. 3(a)**

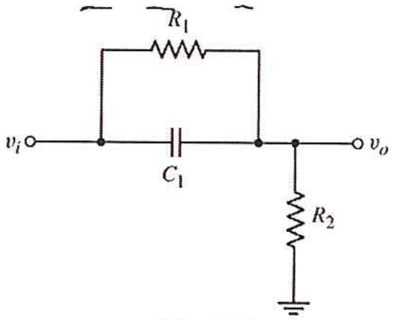


(b) Draw the typical frequency response of an amplifier and explain its behavior.

**(6 marks)**



(c) Consider the circuit shown in **Fig. 3(c)**, derive the expression for the voltage transfer function $T(s) = {v_o(s)}/{v_i(s)}$ . Put expression in the form of $T(s) = K(1+s\tau_A)/(1+s\tau_B)$ . What are the values of $K$, $\tau_A$ and $\tau_B$ ? **(8 marks)**



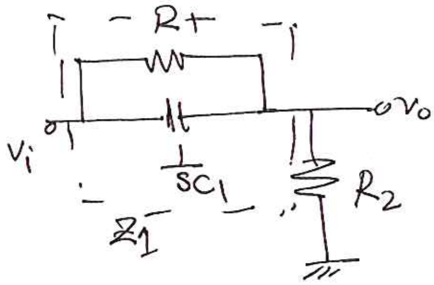




**Fig. 3(c)**

$$Z_1 = R_1 \| \frac{1}{sC_1} = \frac{R_1 \times \frac{1}{sC_1}}{R_1 + \frac{1}{sC_1}} = \frac{R_1}{1 + sC_1R_1}$$

$$\frac{V_o}{V_i} = \frac{R_2}{R_2 + \frac{R_1}{1+sC_1R_1}} = \frac{R_2(1+sC_1R_1)}{R_2(1+sC_1R_1)+R_1}$$

$$= \frac{R_2\,(1+sC_1R_1)}{R_1+R_2 + sC_1R_1R_2} = \frac{R_2}{R_1+R_2} \cdot \frac{(1+sC_1R_1)}{(1+sC_1\frac{R_1R_2}{R_1+R_2})}$$

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

Therefore $K = \frac{R_2}{R_1+R_2}$ ←

$\tau_A = C_1R_1$ ←

$\tau_B = R_1 \| R_2 = \frac{R_1R_2}{R_1+R_2}$ ←

## Useful formulas

### For BJT

For bias stable $R_B = 0.1(1+\beta)R_E$

$$g_m = \frac{I_{CQ}}{V_T}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$

$$r_o = \frac{V_A}{I_{CQ}}$$

$V_T = 0.026$ V

$V_{BE} = 0.7$ V

### For MOSFET

$$g_m = 2\sqrt{k_n I_{DQ}}$$

$$r_o = \frac{1}{\lambda I_{DQ}}$$