MODEL ANSWER

Name:______________________________

Matric No:______________ Section:_____

الجامعة الإسلامية العالمية ماليزيا

# INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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

Programme : ENGINEERING  Level of Study : UG 2

Time : 8:00pm-10:00 pm  Date : 22/03/2013

Duration : 2 Hours

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

Course Title : **Electronic Circuits**

This Question Paper consists of **Seven (7)** Printed Pages (Including Cover and a blank page) with **Two (2)** 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 and values are given in page 7.**
- 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 questions.

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

| | Question 1a | Question 1b | Question 2a | Question 2b | Total Marks |
|---|---|---|---|---|---|
| Marks | 15 | 15 | 15 | 15 | 60 |
| Marks Obtained | | | | | |

**Q.1 [30 marks]**

(a) Determine the Q-point values ($I_{DQ}$ and $V_{DSQ}$) for the circuit shown in **Fig. 1(a)**. The transistor parameters are $V_{TN}$ = 1.2 V, $K_n$ = 0.5 mA/$V^2$ and $\lambda$ = 0. Also calculate the small signal circuit parameters.

**(15 marks)**

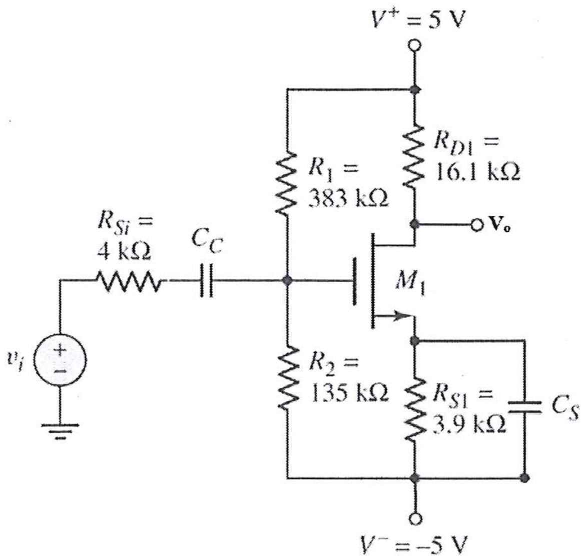
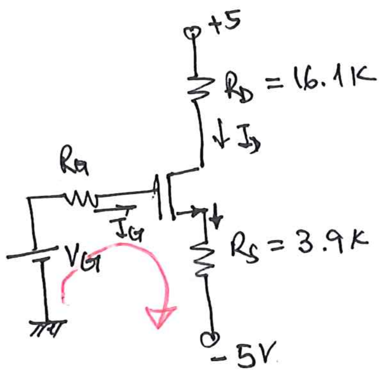



**Fig. 1(a)**




$5 = I_D(R_D + R_S) + V_{DS} - 5$

$\therefore V_{DS} = 5 + 5 - I_D(R_D + R_S)$

$= 10 - 0.19845 \times 20$

$= 6.031$ V

$R_G = R_1 \| R_2 = 383 \| 135 = 99.8167$ KΩ 2

$V_G = \frac{(5+5) \times 135}{135 + 383} \times 135 - 5 = \frac{10 \times 135}{518} - 5 = -2.394$ V 3

$V_G = I_G R_G + V_{GS} + R_S I_S - 5 = V_{GS} + R_S K_n (V_{GS} - V_T)^2 - 5$ ($I_G = 0$) 3

$-2.394 = V_{GS} + 3.9K \times 0.5 mA/V^2 (V_{GS} - 1.2)^2 - 5$

$= V_{GS} + 1.95(V_{GS}^2 - 2.4V_G + 1.44) - 5$

$= 1.95 V_{GS}^2 - 3.68 V_{GS} + 2.808 - 5$ 2

$\therefore 1.95 V_{GS}^2 - 3.68 V_{GS} + 0.202 = 0$

$V_{GS} = 1.83$ V, 0.056 V

choosing $V_{GS} = 1.83 > V_T$.

$I_D = K_n (V_{GS} - V_T)^2 = 0.5(1.83 - 1.2)^2$ 2

$= 0.19845$ mA

$g_m = 2\sqrt{K_n I_{DQ}} = 2\sqrt{0.5 \times 0.19845}$ 3

$= 0.63$ mA/V

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

(b) For the circuit shown in **Fig 1(b)**, design a bias stable circuit such that $I_{CQ}$ = 0.8 mA and $V_{CEQ}$ = 5.0 V assuming $\beta$=100. Also find small signal parameters $g_m$, $r_\pi$ and $r_o$ if $V_A$ = 100. [Hints: determine the values of $R_C$, $R_1$ and $R_2$]

**(15 marks)**

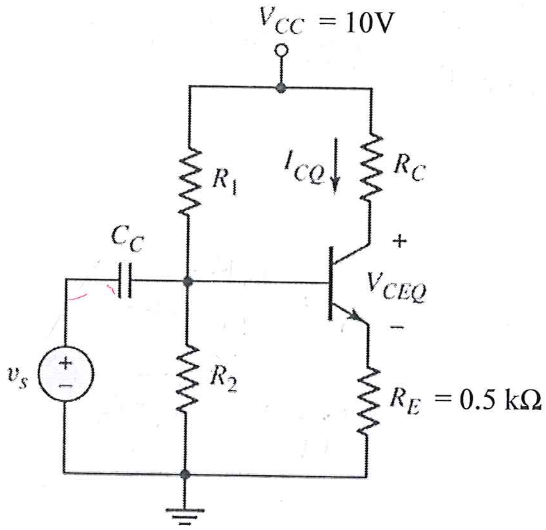
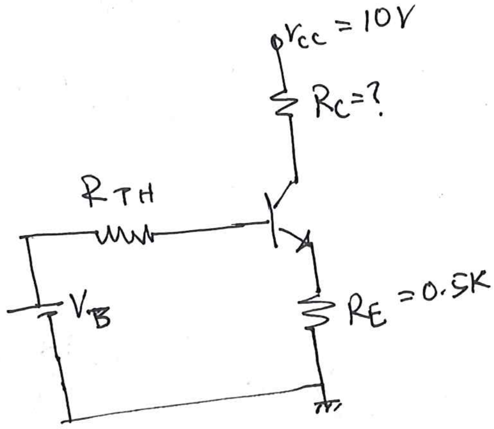



**Fig. 1 (b)**




For bias stable, $R_{TH} = R_B = 0.1(1+\beta)\times R_E = 0.1(1+100)\times 0.5K$

$= 5.05\ k\Omega$

$V_{CC} = I_C R_C + V_{CEQ} + I_E R_E$

$= I_C R_C + V_{CEQ} + (1+\beta) I_B R_E$

$\therefore I_C R_C = V_{CC} - V_{CEQ} - \frac{(1+\beta) I_C R_E}{\beta}$

$= 10 - 5 - \frac{101}{100} \times 0.5k \times 0.8m$

$= 4.5960$

$\therefore R_C = 5.745\ k\Omega$

$$V_B = I_B R_B + V_{BE} + I_E R_E$$

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

$$= \frac{0.8}{100} \times 5.05 + 0.7 + \frac{101}{100} \times 0.8 \times 0.5$$

$$= 0.0404 + 0.7 + 0.404 = 1.1444 \text{ V}$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2}$$

$$V_B = \frac{V_C R_2}{R_1 + R_2} = \frac{V_C R_B}{R_1}$$

$$\frac{R_B}{R_1} = \frac{R_2}{R_1 + R_2}$$

$$\therefore R_1 = \frac{V_C}{V_B} \cdot R_B$$

$$= \frac{10}{1.1444} \times 5.05\text{k} = 44.128 \text{ k}\Omega$$

$$R_2 = \frac{1}{\frac{1}{R_B} - \frac{1}{R_1}} = 5.70 \text{ k}\Omega$$

$$\frac{1}{R_B} = \frac{1}{R_1} + \frac{1}{R_2}$$

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

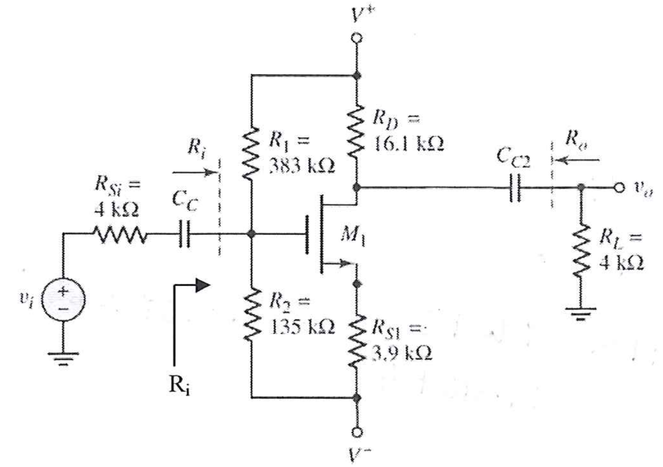
$$\beta = g_m r_\pi$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{30.77} = 3.25 \text{ k}\Omega$$

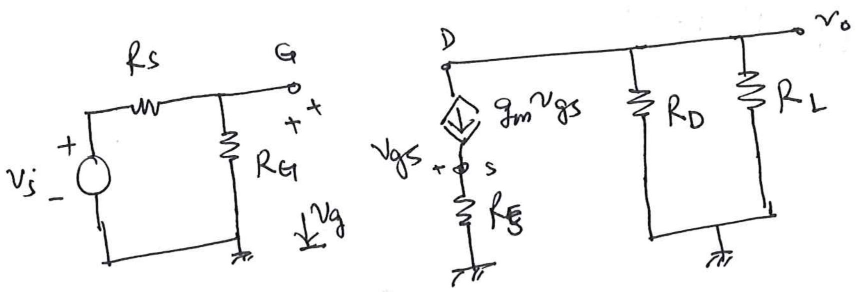
$$r_o = \frac{V_A}{I_{CQ}} = \frac{80}{0.8} = 100 \text{ k}\Omega$$

**Q.2 [20 marks]**

(a) Draw the small signal equivalent circuit diagram of the MOSFET amplifier 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. The transistor parameters are $g_m$=0.65 mA/V and $\lambda = 0$. **(15 marks)**



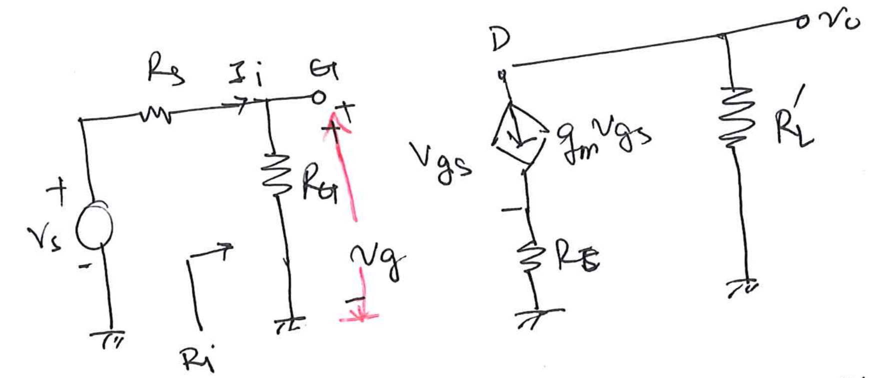

$\lambda = 0 \quad r_o = \infty$




$R_i = \frac{v_g}{I_i} = \frac{R_G I_i}{I_i}$

$= R_G = R_1 \| R_2$

$= 99.816\,k\Omega$




$v_o = - g_m v_{gs} \times R_L'$

$v_g = v_{gs} + g_m v_{gs} R_E$

$= v_{gs}(1 + g_m R_E)$

$\therefore A_{vA} = \frac{v_o}{v_g} = \frac{-g_m v_{gs} R_L'}{v_{gs}(1+g_m R_E)}$

$= -\frac{g_m R_L'}{1 + g_m R_S}$

$$A_{v_A} = \frac{-g_m R_L'}{1 + g_m R_s}$$

$$R_L' = 16.1 \| 4$$
$$= 3.204 K\Omega$$

$$= \frac{-0.65 \times 3.204}{1 + 0.65 \times 3.9} = -0.5891$$

$$\therefore A_v = \frac{v_o}{v_s} = A_{v_A} \times \frac{R_i}{R_i + R_s}$$

$$= -0.5891 \times \frac{99.816}{99.816 + 4} = -0.5664$$ ←

$$R_i = 99.816 K\Omega$$ ←

(b) Draw the small signal equivalent circuit diagram of the BJT amplifier circuit shown in **Fig. 2(b)** and find the current gain $A_i = \frac{I_o}{I_i}$ and output resistance $R_o$ where $I_o$ is the current flowing through $R_L$. Given that $R_1 = 300\ k\Omega$, $R_2 = 500\ k\Omega$, $R_E = 20.0\ k\Omega$ and $I_D = 0.25\ mA$. The transistor parameters are $\beta = 100$, $V_{BE\,(on)} = 0.7\ V$ and $VA = 80$. **(15 marks)**

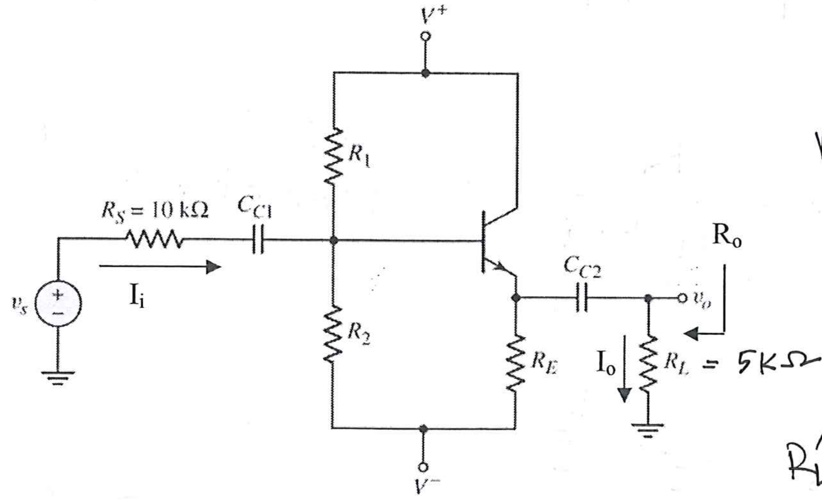
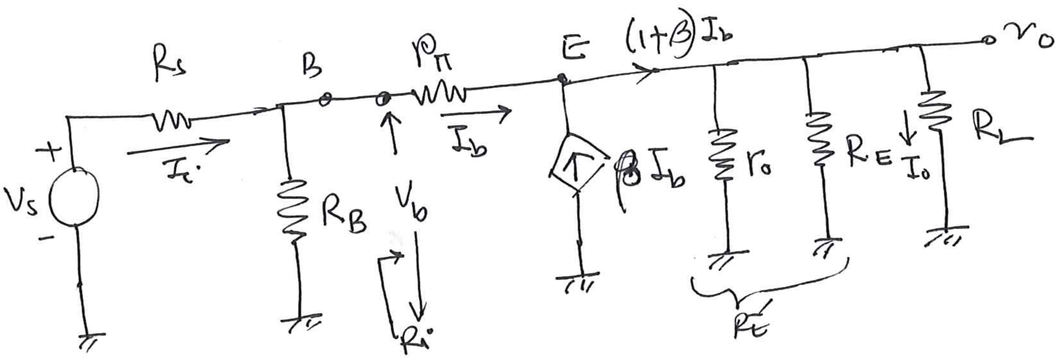



**Fig. 2(b)**

$r_o = \frac{VA}{I_C} = \frac{80}{0.25m} = 320K\Omega$

$r_\pi = \frac{\beta V_T}{I_C} = \frac{100 \times 0.026}{0.25} = 10.4 K\Omega$

$R_L' = r_o \| R_E \| R_L = 320\|20\|5 = 3.95 K\Omega$




$R_E' = r_o \| R_E = 320\|20 = 18.82\ K\Omega$

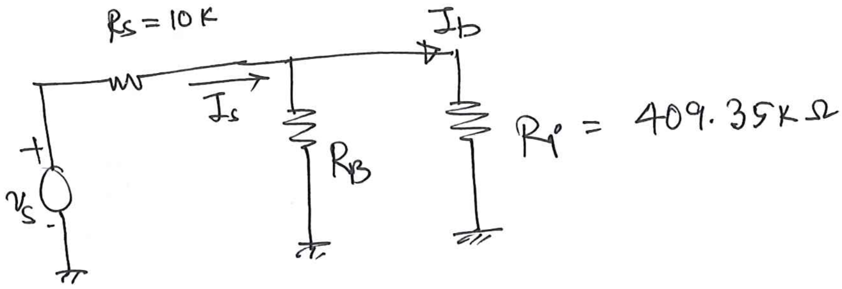
$I_o = \frac{I_b(1+\beta) \times R_E'}{R_L + R_E'} = 101\, I_B \times \frac{18.82}{5 + 18.82} = 79.787\, I_b$

$R_i = \frac{V_b}{I_b} = \frac{r_\pi I_b + I_b(1+\beta) R_L'}{I_B} = r_\pi + (1+\beta) R_L'$

$= 10.4 + 101 \times 3.95$

$= 409.35\ K\Omega$

$R_B = R_1 \| R_2$
$= 300 \| 500 = 187.5K$

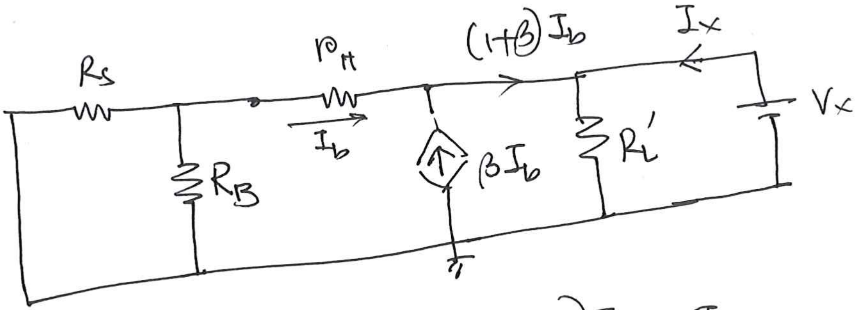



$$\frac{I_b}{I_s} = \frac{R_B}{R_B + R_i} = \frac{187.5}{187.5 + 409.35} = 0.3141$$

$$\therefore A_I = \frac{I_o}{I_s} = \frac{I_o}{I_b} \cdot \frac{I_b}{I_s}$$

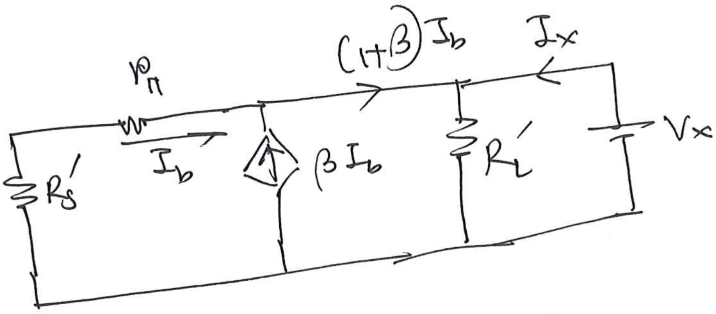
$$= ~~78.~~ = 79.787 \times 0.3141 = 25.065$$

$R_o = ?$




$R_s' = R_B \| R_s$
$= 187.5 \| 10$
$= 9.494 k\Omega$

$r_\pi = 10.4 k\Omega$




$$I_b = -\frac{V_x}{r_\pi + R_s'}$$

$$I_x = \frac{V_x}{R_L'} - (1+\beta) I_b$$

$$= \frac{V_x}{R_L'} + \frac{(1+\beta) V_x}{r_\pi + R_s'} = \frac{V_x}{R_L'} + \frac{V_x}{\frac{r_\pi + R_s'}{(1+\beta)}}$$

$$\therefore \frac{1}{R_o} = \frac{1}{R_L'} + \frac{1}{\frac{r_\pi + R_s'}{(1+\beta)}} \quad \therefore R_o = R_L' \| \left(\frac{r_\pi + R_s'}{1+\beta}\right)$$

$$\therefore \frac{r_\pi + R_s'}{1+\beta} = \frac{10.4 + 9.494}{1+100} = 0.19696 \ k\Omega$$

$$\therefore R_o = 3.95k \| 0.19696 k\Omega = 0.1876 \ k\Omega$$

$$= 187.611 \ \Omega$$

**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

$V_{BE(on)} = 0.7$ V

**For MOSFET**

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

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

***Large values of capacitors are connected to the circuits as coupling and bypass capacitors.***