GUC German University in Cairo

IET, Electronics Department
Electronic Circuits for Mechatronics (ELCT 609)
Mid-term Exam Spring 2016
Dr. Eman Azab

Model Answer

Bar Code

Eman Azab

Electronic Circuits for Mechatronics (ELCT 609)
Spring Semester 2016
Mid-term Exam

Instructions: **Read Carefully Before Proceeding.**

1- No programmable/storing calculators, book or other aids are permitted for this test.

2- Write your solutions in the space provided. If you need more space, write on the back of the sheet containing the problem.

3- **Answer all questions.**

4- Read all the problems carefully before starting, and start with the easiest question you find.

5- This exam booklet contains **13** pages, including this one., This exam consists of **FOUR** questions

6- When you are told that time is up, stop working on the test.

7- Total time allowed for this exam is ***120 min.***

Good Luck!

Question Number	1	2	3	4	Total
Maximum Score	20	20	30	35	105
Obtained Score					Max. 100

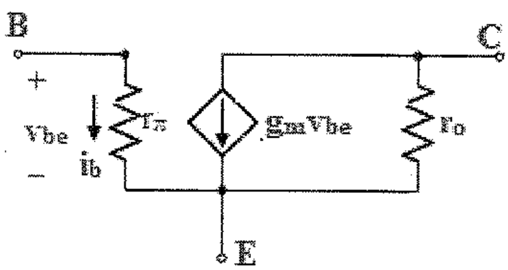
Maged   Lobna   Mariam   Eman

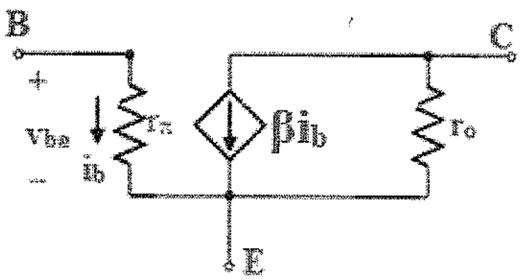
Formula Sheet

- ## BJT: Modes of Operation

Mode	I-V Characteristics
Cutoff	$I_C = I_E = I_B = 0$
Active (Forward)	$V_{BE} = 0.7V$, $I_E = I_C + I_B$, $I_C = \beta_F I_B$
Saturation	$V_{CE} = 0.2V$, $I_E = I_C + I_B$
Reverse Active	$V_{BC} = 0.5V$, $I_C = I_E + I_B$, $I_E = \beta_R I_B$

- ## BJT: Small Signal Model

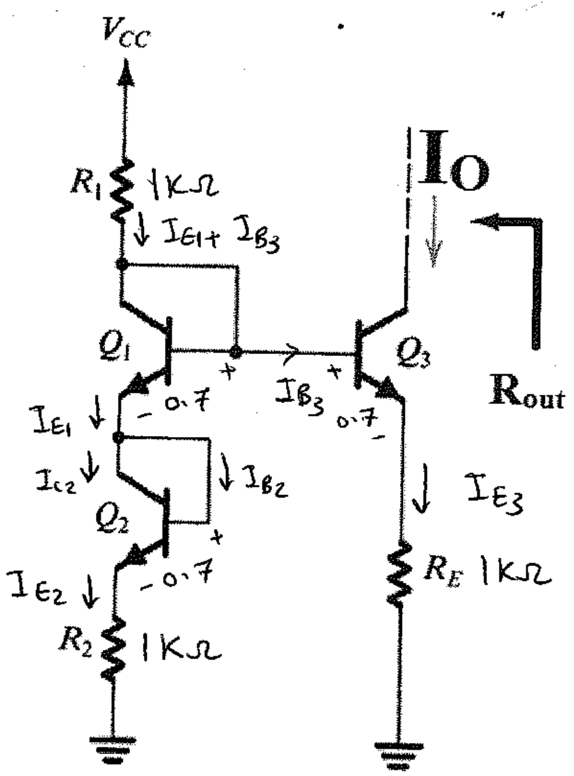


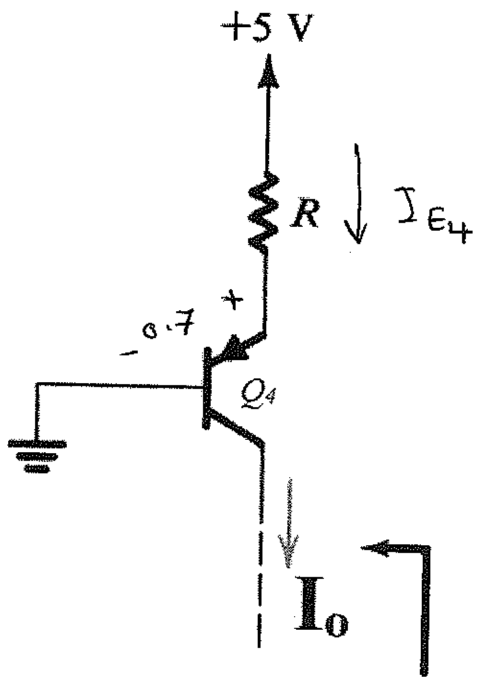


$$g_m = \frac{I_C}{V_T}, \; r_\pi = \frac{\beta}{g_m}, \; r_o = \frac{V_A}{I_C}, \; V_T = 25mV$$

Problem 1: (20 marks)

The two circuits shown are current sources, find their Output current I_o and their output resistance R_{out}.
V_{CC}=10V, V_{BE} or V_{EB}=0.7V, β_F=100, $R_1=R_2=R_E=1k\Omega$, $R=2.15k\Omega$
(**Hint:** Assume that ALL Transistors are active, Draw the small signal model to calculate the output resistance)





KVL ①

$$10 = (I_{E1}+I_{B3})\,1K + 0.7 + 0.7 + I_{E2} \times 1K$$

$$\boxed{\therefore 8.6 = 2 I_{E1} + \frac{I_{E3}}{101}}$$ ① $\boxed{3}$

KVL ②

$$0.7 + I_{E3} \times 1K = 0.7 + 0.7 + I_{E2} \times 1K$$

$$\boxed{I_{E2} = I_{E3} - 0.7}$$ ② $\boxed{3}$

KCL $\boxed{I_{E1} = I_{E2}}$ ③

$$I_{E4} = \frac{5-0.7}{2.15K}$$

$$\cong 2mA$$ $\boxed{10}$

$$I_o = I_{C4} = I_{E4}\frac{\beta}{1+\beta}$$

$$\boxed{I_o = 1.98mA}$$

$\because V_A = 0 \quad r_o = \infty$ (not given)

$$\boxed{R_{out} = \infty}$$

$\therefore$ sub in (2) by (3)

$\boxed{I_{E1} = I_{E3} - 0.7}$ (4)

solve (4) & (1)

$8.6 = 2\, I_{E3} - 1.4 + \frac{I_{E3}}{101}$

$10 = \left(2 + \frac{1}{101}\right) I_{E3}$

$\therefore \boxed{I_{E3} \cong 5\,mA}$

$I_o = I_{C3} = \frac{\beta}{1+\beta} I_{E3}$

$\boxed{I_o = 4.95\,mA}$

- for Rout $\boxed{4}$

$\because V_A = 0 \qquad r_o = \infty$

$\therefore \boxed{R_{out} = \infty}$

Problem 2: (20 marks)

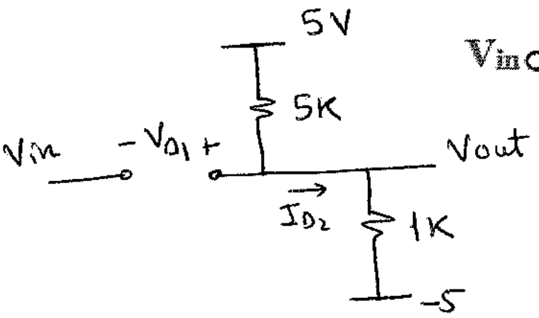
D1 and D2 are ideal diodes, 'V_{in}' is a sinusoidal signal with 1 kHz frequency and amplitude voltage of 10V, Analyze the circuit to:

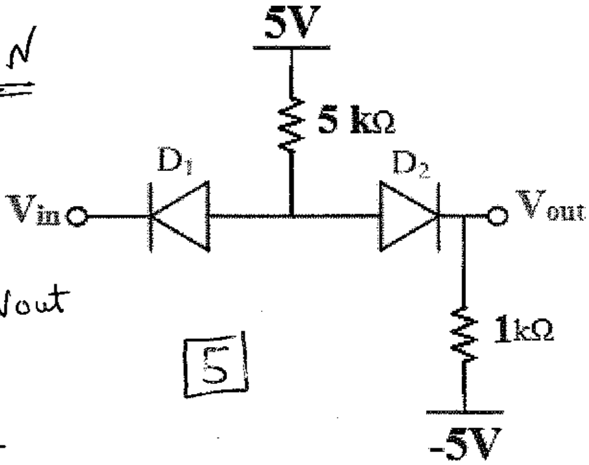
A. Plot 'V_{out}' versus 'V_{in}'

B. Plot 'V_{out}' versus Time

Case ①

D_1 off & D_2 ON





$\boxed{5}$

$V_{out} = 5 \times \frac{1}{6} - 5 \times \frac{5}{6} = -3.33V$

$\therefore \boxed{V_{out} = -3.33\ V}$

Condition $\quad I_{D2} > 0$ ✓ $\quad V_{D1} < 0 \quad -V_{in} + V_{out} < 0$

$\boxed{V_{in} > -3.33V}$

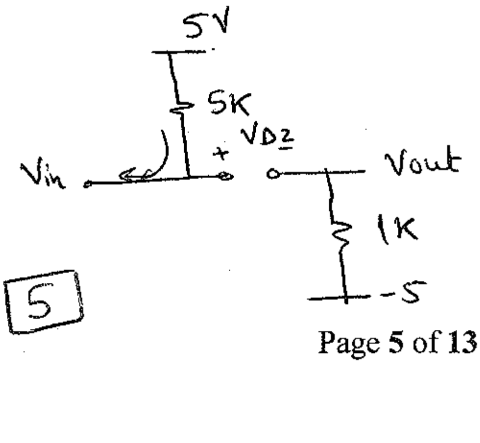
Case ② $\quad D_1$ ON , D_2 off

$\boxed{V_{out} = -5V}$

Condition $\quad I_{D1} > 0$

$V_{in} - V_{out} < 0$

$\boxed{V_{in} < -5}$



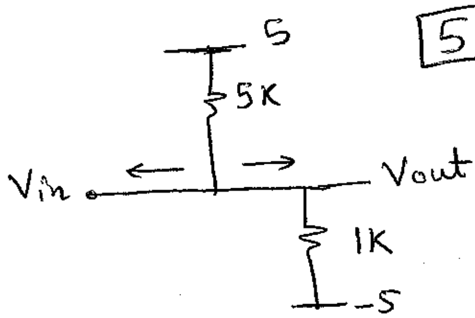
$\boxed{5}$

Case 3

D_1 & D_2 ON

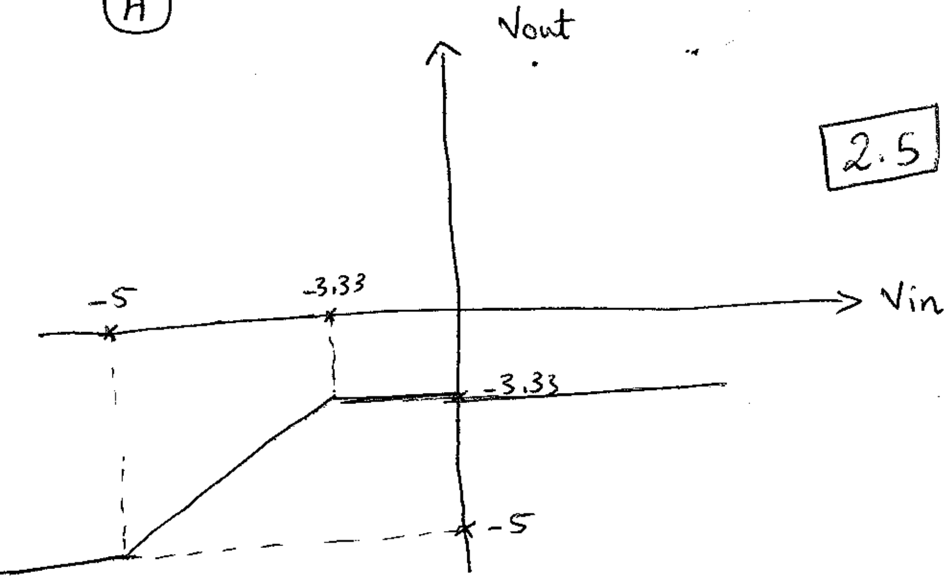
$\boxed{V_{out} = V_{in}}$

$\boxed{-5 < V_{in} < -3.33}$



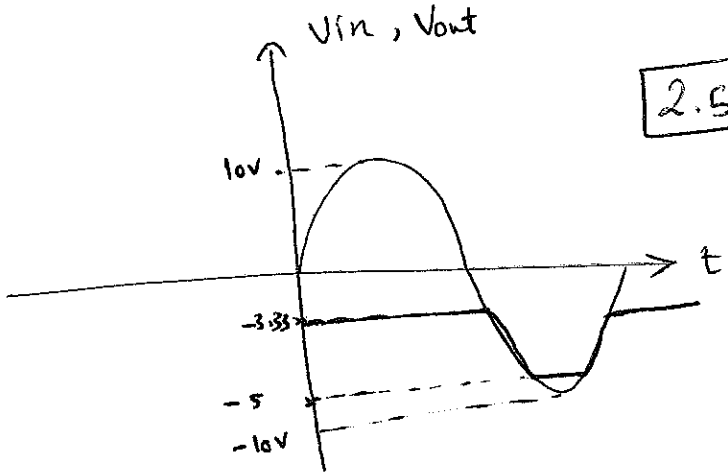
5

(A)



2.5

(B)

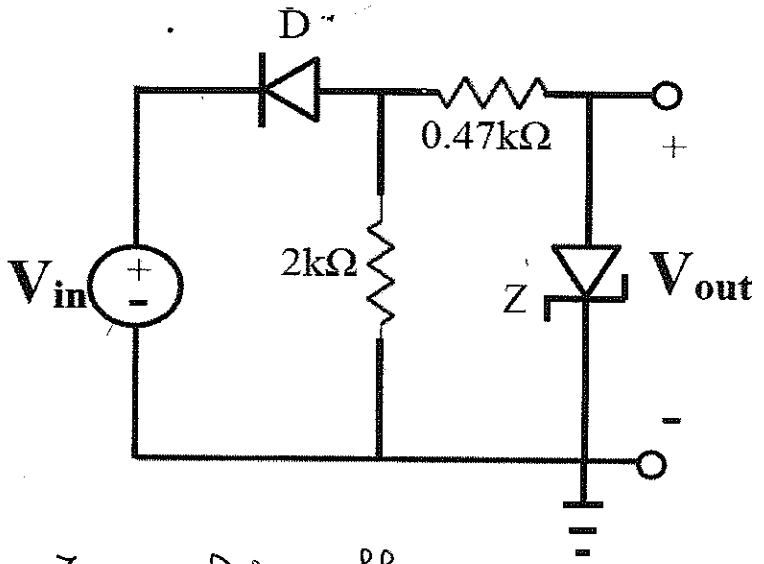


2.5

Problem 3: (30 Marks)

In the circuit shown, the Zener diode has $V_Z = 6.8V$ and $r_Z = 20\Omega$ while the normal diode D has $V_{th} = 0.7V$. The input voltage 'V_{in}' is a 20-V peak-to-peak sinusoidal signal with an average value of 0V.

- Derive an expression for the output signal 'V_{out}' over the range of 'V_{in}'
- Sketch 'V_{out}' versus 'V_{in}'

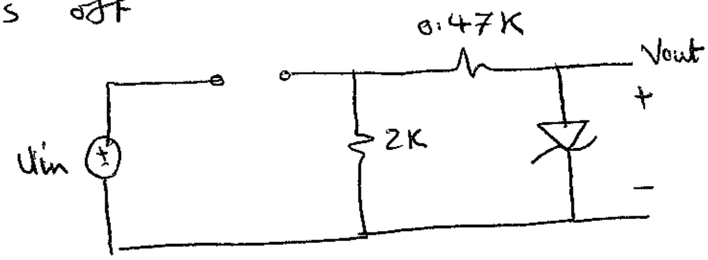


$\boxed{10}$

for $V_s > -0.7$ D is off

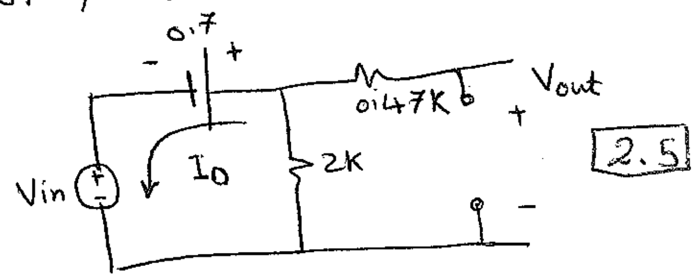
& Z is off

$\therefore \boxed{V_{out} = 0}$



for $V_s < -0.7$ D is ON, assume Z is off

$\boxed{V_{out} = V_{in} + 0.7}$ $\boxed{5}$



$I_D > 0$

V_{out} should be :

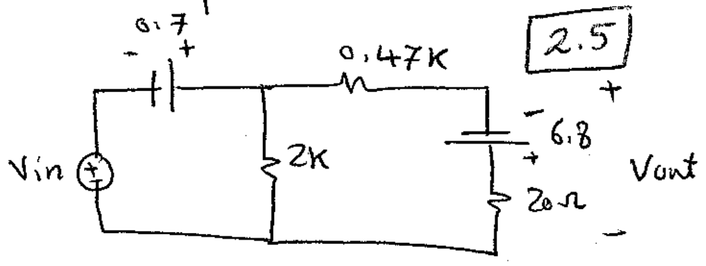
$-V_Z < V_{Zener} < 0.7$

$-V_Z < V_{in} + 0.7 < 0.7$

$V_{in} > -0.7 - 6.8$ $\boxed{V_{in} > -7.5}$

for $V_{in} < -7.5$ Zener will operate in Breakdown

$\boxed{2.5}$

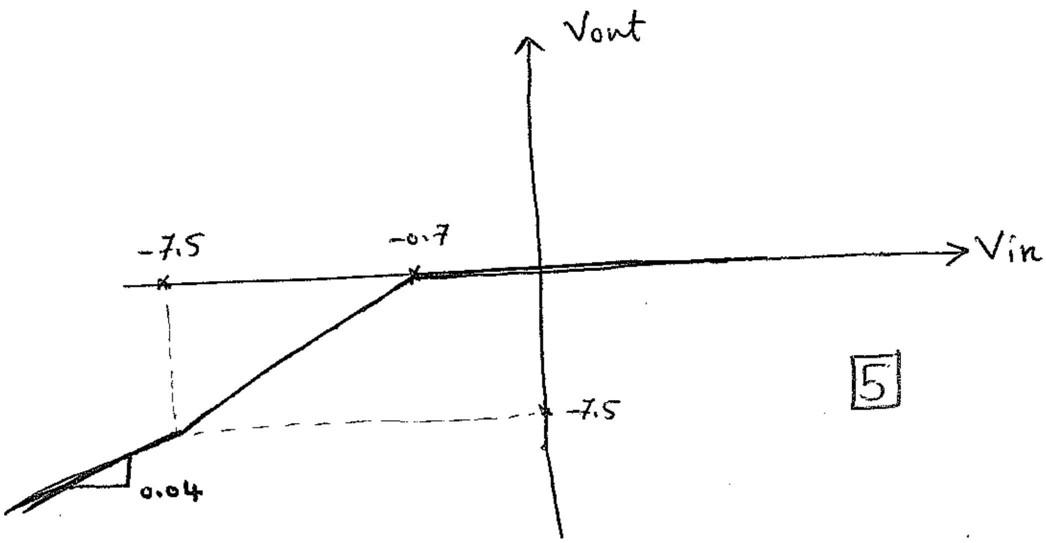


$$V_{out} = -6.8 - I \times 20$$

$$I = \frac{-6.8 - 0.7 - V_{in}}{0.49K}$$

$$\boxed{V_{out} = -6.8 + 0.04V_{in}}$$ $\boxed{5}$

$$\therefore \quad V_{out} = \begin{cases} 0 & V_{in} > -0.7 \\ V_{in} + 0.7 & -7.5 < V_{in} < -0.7 \\ -6.8 + 0.04V_{in} & V_{in} < -7.5 \end{cases}$$

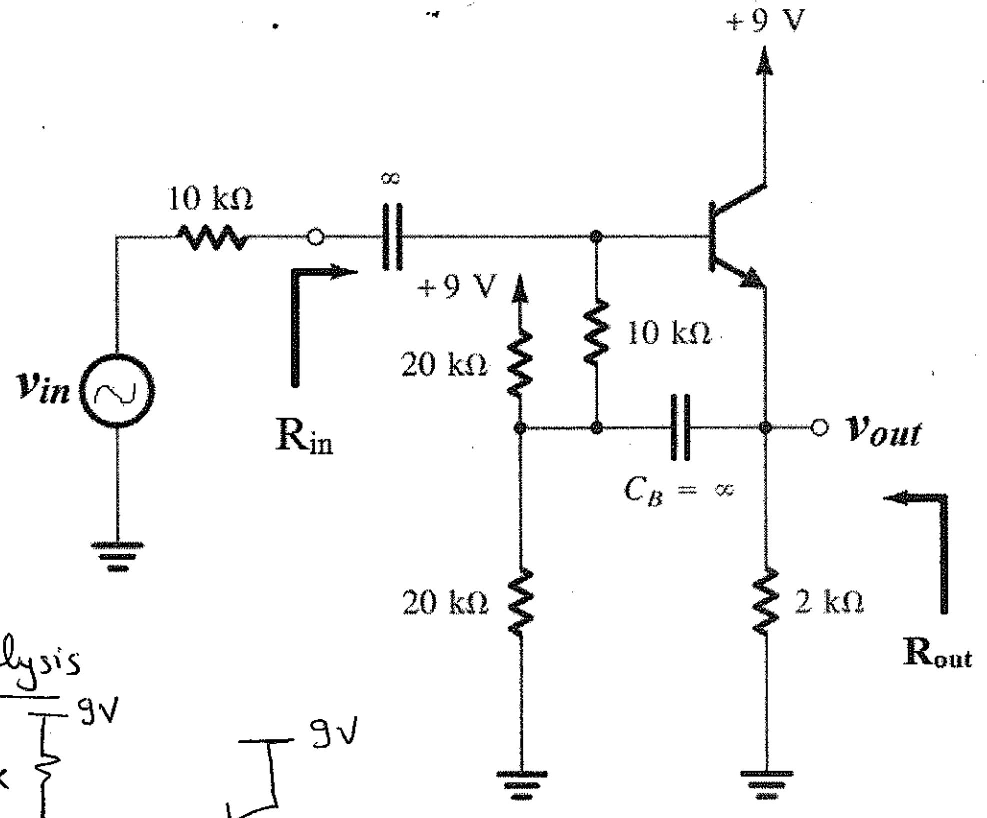


$\boxed{5}$

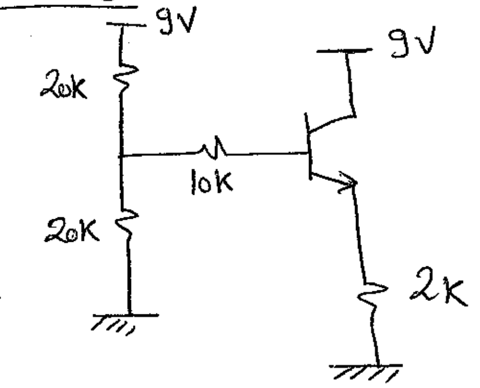
Problem 4 (35 marks)

For the Common Collector amplifier shown, V_{BE}=0.7V, β_F=100 calculate:

1. The voltage gain '**Vout/Vin**'
2. The Input Resistance '**R_{in}**'
3. The Output Resistance '**R_{out}**'



DC Analysis



KVL

$4.5 - 0.7 = 20 I_B + 2 I_E$

$\boxed{5}$ $= 20 I_B + 2 \times 101 I_B$

$I_B = \frac{4.5 - 0.7}{222}$

$I_B = 0.0171 \text{ mA}$

$I_C = \beta I_B = 1.711 \text{mA}$

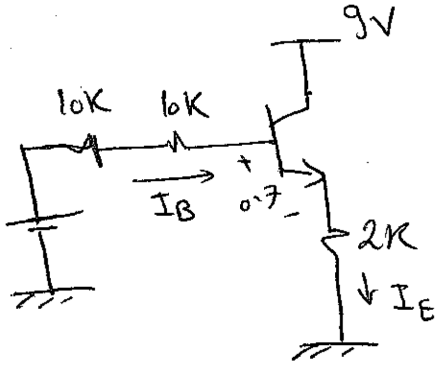
using thevenin

$V_{th} = 9 \times \frac{20}{40}$

$= 4.5V$

$R_{th} = 20K // 20K$

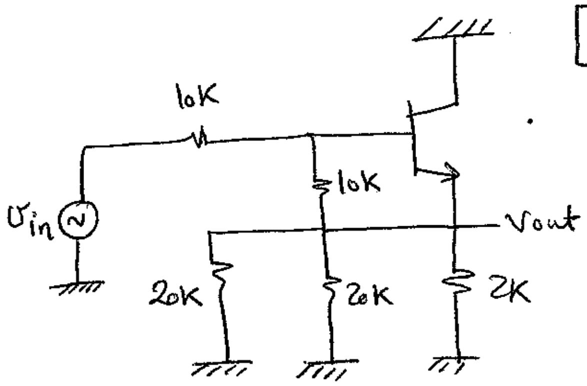
$= 10K\Omega$



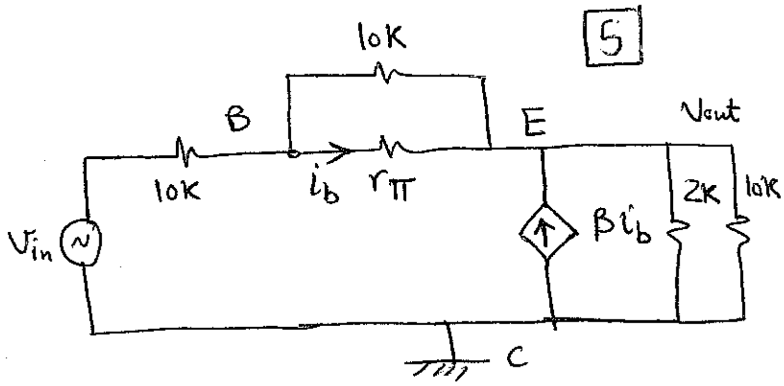
$\therefore \; r_\pi = \dfrac{\beta}{g_m}$

$g_m = \dfrac{I_C}{V_T} = 68.5 \text{ mA/V}$ $\qquad r_\pi = 1.48 \text{ k}\Omega$

* AC Analysis



5



5

$$v_{out} = \left[(1+\beta)i_b + \frac{i_b r_\pi}{10K}\right] \times (2K // 10K) \qquad \boxed{5}$$

$$V_{in} = \left[\frac{i_b r_\pi}{10K} + i_b\right] 10K + i_b r_\pi + v_{out}$$

$$= \left[\frac{i_b r_\pi}{10K} + i_b\right] 10K + i_b r_\pi + \left[\left(1+\beta+\frac{r_\pi}{10K}\right) i_b \times (2K // 10K)\right] \qquad \boxed{5}$$

$$\therefore \frac{V_{out}}{V_{in}} = \frac{\left(1+\beta+\frac{r_\pi}{10K}\right)(2K // 10K)}{\left[10K + 2r_\pi + \left(1+\beta+\frac{r_\pi}{10K}\right)(2K//10K)\right]}$$

$$= \frac{101.146 \times 1.667}{(10 + 2.92 + 101.146 \times 1.667)} = \frac{168.61}{181.53}$$

$$= 0.9288 \cong \boxed{0.923}$$

$$R_{in} = \frac{v_{in}}{i_{in}}$$

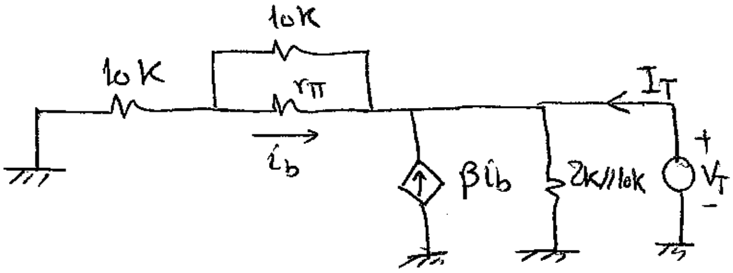
$$i_{in} = i_b\left(1 + \frac{r_\pi}{10K}\right)$$

$\boxed{5}$

$$\therefore R_{in} = \frac{i_b\left[2r_\pi + 10K + \left(1+\beta+\frac{r_\pi}{10K}\right)(2K//10K)\right]}{i_b\left(1+\frac{r_\pi}{10K}\right)}$$

$$\therefore R_{in} = \frac{2\times1.46 + 10K + 168.61}{1 + 0.146} = \boxed{158.4\ K\Omega}$$

$$R_{out} = \left.\frac{V_T}{I_T}\right|_{v_{in}=0}$$



$$V_T = -i_b r_\pi - i_b\left(\frac{r_\pi}{10K}+1\right)10K$$

$$I_T = \frac{V_T}{2K//10K} - i_b - \beta i_b - \frac{i_b r_\pi}{10K}$$

$\boxed{5}$

$$\therefore i_b = -V_T\,\frac{1}{(2r_\pi + 10K)}$$

$$\therefore I_T = V_T\left[\frac{1}{2K//10K} + \frac{\left(1+\beta+\frac{r_\pi}{10K}\right)}{2r_\pi+10K}\right]$$

$$R_{out} = \left[\frac{1}{2K//10K} + \frac{\left(1+\beta+\frac{r_\pi}{10K}\right)}{2r_\pi+10K}\right]^{-1}$$

$$= \left[\frac{1}{1.667K} + \frac{101.148}{12.92}\right]^{-1}$$

$$= \frac{1}{8.4285}\ K\Omega = \boxed{0.1186\ K\Omega}$$