Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Fall 2022

Exam #2

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are **6** pages in your exam
- Good Luck!

Problem	Score	Max Score
1		10
2		20
3		35
4		35
Total		**100**

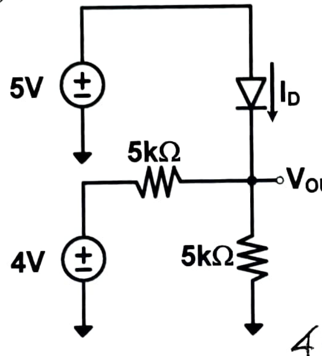
Name: SAM PALERMO

UIN:

Problem 1 (10 points)

For all the circuits below, use the constant-voltage-drop diode model (V_D=0.7V), V_{th}=25.9mV, and n=1.

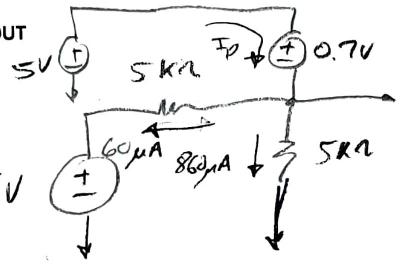
a) Find V_{OUT}, I_D, and the small signal diode resistance, r_d.



If Diode is OFF ⟹ V_{OUT} = 2V, V_D = 3V, Wrong

Diode is ON

I_D = 920μA



V_{OUT} = 4.3V

$$r_d = \frac{V_{th}}{I_D} = \frac{25.9mV}{920\mu A} = 28.2\Omega$$

V_{OUT} = 4.3V

I_D = 920μA

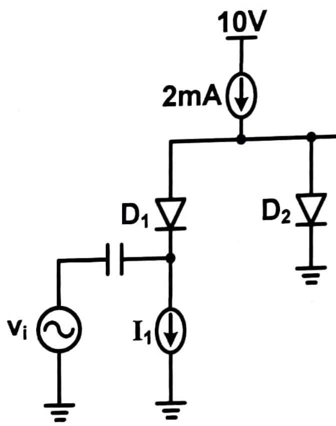
r_d = 28.2Ω

Problem 2 (20 points)

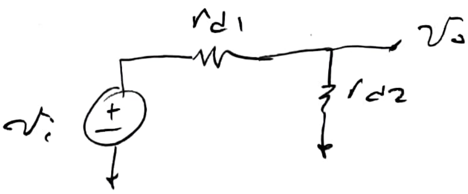
Assume for the following circuit that **all diodes are forward biased**. Also assume that the capacitors act as AC shorts.

a) Derive an expression for the small-signal gain $A_v=v_o/v_i$. (10 points)

b) Calculate the value of I_1 for A_v=0.4 (10 points)



AC Equivalent Circuit



$$\frac{v_o}{v_i} = \frac{r_{d2}}{r_{d1} + r_{d2}}$$

$$\frac{r_{d2}}{r_{d1} + r_{d2}} = 0.4$$

$$r_{d2} = \frac{2}{3} r_{d1} \Rightarrow I_{D2} = \frac{3}{2} I_{D1}$$

$$I_{D1} + I_{D2} = 2mA$$

$$\frac{5}{2} I_{D1} = 2mA$$

$$I_{D1} = 0.8mA = I_1$$

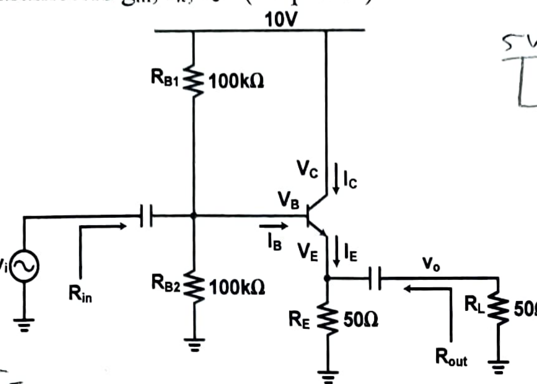
A_v Expression = $\frac{r_{d2}}{r_{d1} + r_{d2}}$

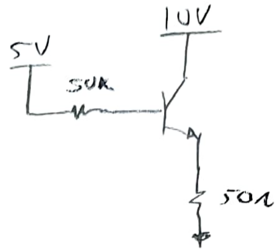
I_1 (A_v=0.4) = 0.8mA

Problem 3 (35 points)

Assume for problem 2 that the transistor $\beta=150$, $V_{BE}=0.7V$, and $V_{th}=25.9mV$.

a) Calculate the DC values for V_C, V_B, V_E, I_C, I_B, and I_E. Compute the AC small signal parameters g_m, r_π, r_e. (18 points)





$I_E = \frac{5V - 0.7V}{50 + \frac{50k}{151}} = 11.3mA$

$I_B = \frac{I_E}{\beta+1} = 74.7\mu A$, $I_C = \beta I_B = 11.2mA$

$V_E = I_E R_E = 11.3mA(50\Omega) = 0.57V$

$V_B = V_E + 0.7 = 1.27V$

$V_C = 10V$

$g_m = \frac{I_C}{V_{th}} = \frac{11.2mA}{25.9mV} = 432\ mA/V$

$r_\pi = \frac{V_{th}}{I_B} = \frac{25.9mV}{74.7\mu A} = 347\Omega$

$r_e = \frac{V_{th}}{I_E} = \frac{25.9mV}{11.3mA} = 2.29\Omega$

$I_C = 11.2mA$

$I_B = 74.7\mu A$

$I_E = 11.3mA$

$V_C = 10V$

$V_B = 1.27V$

$V_E = 0.57V$

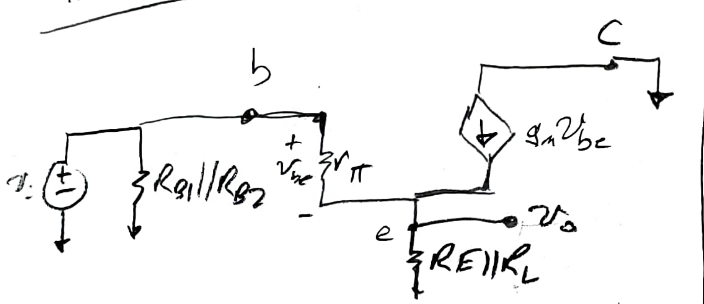
$g_m = 432\ mA/V$

$r_\pi = 347\Omega$

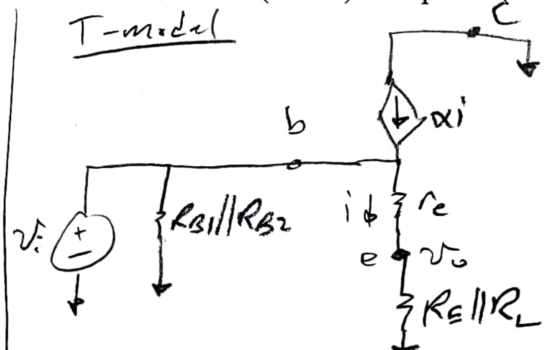
$r_e = 2.29\Omega$

b) Sketch the small-signal model of the circuit. Assume that the capacitors act as AC shorts and that the transistor's r_o is infinite. Only **ONE** version of the model (π or T) is required (11 points)

π-Model



T-model



c) Calculate the small signal gain $A_v=v_o/v_i$, the input resistance R_{in}, the output resistance R_{out}. (6 points)

$A_v = \frac{R_E||R_L}{r_e + R_E||R_L} = \frac{50||50}{2.29 + 50||50} = 0.916\ V/V$

$R_{in} = R_B||[r_\pi + (\beta+1)(R_E||R_L)] = 50k||[347 + (151)(50||50)] = 3.81k\Omega$

$R_{out} = r_e||R_E = 2.29||50 = 2.19\Omega$

$A_v = 0.916\ V/V$

$R_{in} = 3.81k\Omega$

$R_{out} = 2.19\Omega$

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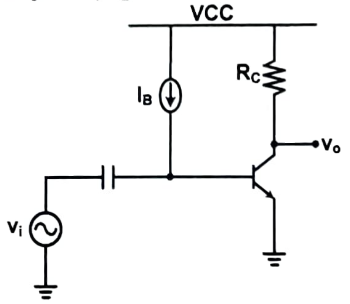
Problem 1 (35 points)
Assume for problem 3 that **the transistors are operating in active mode** and that the capacitors act as AC shorts and that the transistor's r_o is infinite (can be neglected).

a) For the amplifier below derive an expression for the small signal gain $A_v = v_o/v_i$ **as a function of β**. (6 points)



$$A_v = -g_m R_C = -\frac{I_C}{V_{th}} R_C = -\frac{\beta I_B}{V_{th}} R_C$$

A_v (β) Expression : $-\frac{\beta I_B}{V_{th}} R_C$

b) Now assume that I_B=10μA, R_C=270Ω, and V_{th}=25.9mV. Calculate A_v for a β of 150 and 300. (4 points)

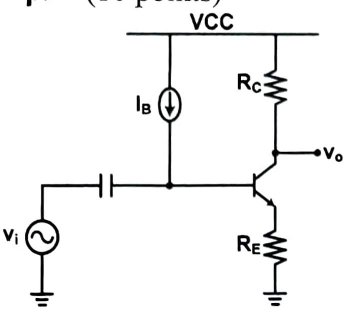
$$A_{v1} = -\frac{150(10\mu A)}{25.9mV}(270\Omega) = -15.6\ V/V$$

$$A_{v2} = -\frac{300(10\mu A)}{25.9mV}(270\Omega) = -31.3\ V/V$$

A_v (β_1=150) = −15.6 V/V

A_v (β_2=300) = −31.3 V/V

c) For the amplifier below derive an expression for the small signal gain $A_v=v_o/v_i$ **as a function of β**. (10 points)



$$A_v = \frac{-g_m R_c}{1+\frac{g_m R_E}{\alpha}} = \frac{-\frac{\beta I_B}{V_{th}} R_c}{1+\frac{\beta I_B}{V_{th}}\left(\frac{\beta+1}{\beta}\right) R_E}$$

A_v (β) Expression :

$$\frac{-\frac{\beta I_B}{V_{th}} R_C}{1+\frac{I_B(\beta+1)}{V_{th}} R_E} = \frac{-\left(\frac{\beta}{\beta+1}\right) R_C}{R_E+\frac{V_{th}}{I_B(\beta+1)}}$$

d) Now assume that the nominal transistor $\beta_1=150$, $R_C=1.5k\Omega$, $I_B=10\mu A$, and $V_{th}=25.9mV$. If β increases, the gain will increase also. However, having an R_E lowers the amplifier sensitivity to β. What is the minimum value of R_E required to insure that if β doubles to $\beta_2=300$ the gain will change no more than 10%? (10 points)

$$A_v(\beta_2=300) = 1.1(\beta_1=150)$$

$$\frac{-\frac{300(10\mu A)}{25.9mV}(1.5k\Omega)}{1+\frac{10\mu A(301)}{25.9mV}R_E} = -\frac{\frac{1.1(150)(10\mu A)}{25.9mV}(1.5k\Omega)}{1+\frac{10\mu A(151)}{25.9mV}R_E}$$

$$\frac{174}{1+0.116R_E} = \frac{95.6}{1+0.058R_E}$$

$$R_E = 83.0\Omega$$

Min. R_E for $A_v(\beta_2=300) = 1.1*A_v(\beta_1=150)$: 83.0Ω

e) Using the R_E value computed in part (d), calculate A_v for a β of 150 and 300. Again, assume $R_C=1.5k\Omega$, $I_B=10\mu A$, and $V_{th}=25.9mV$. (5 points)

$$A_v(\beta=150) = \frac{-\frac{150(10\mu A)}{25.9mV}(1.5k)}{1+\frac{10\mu A(151)}{25.9mV}(83)} = -14.9\,V/V$$

$$A_v(\beta=300) = \frac{-\frac{300(10\mu A)}{25.9mV}(1.5k)}{1+\frac{10\mu A(301)}{25.9mV}(83)} = -16.3\,V/V$$

A_v ($\beta_1=150$) = $-14.9\,V/V$

A_v ($\beta_2=300$) = $-16.3\,V/V$