Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Spring 2020

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		30
2		35
3		35
Total		**100**

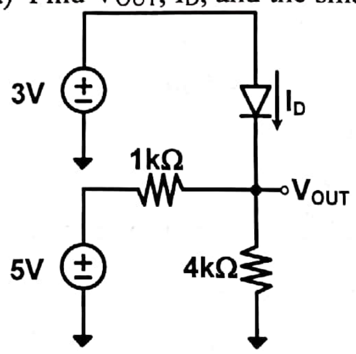
Name: SAM PALERMO

UIN:

Problem 1 (30 points)

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

a) Find V_{OUT}, I_D, and the small signal diode resistance, r_d. (10 points)



If diode is reverse biased

$V_{OUT} = 4V$

$V_D = -1V$ and $I_D = 0$

$\Rightarrow$ Consistent w/ diode model

$r_d = \frac{V_T}{I_D} = \frac{25.9mV}{0} = \infty$

V_{OUT} = 4V

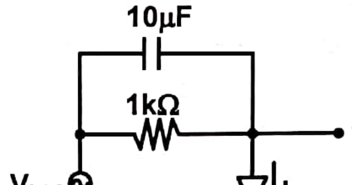
I_D = 0

$r_d = \infty$

The following circuit has a small-signal AC signal, $v_{i,AC}$, in series with a DC voltage.

b) Find the DC output voltage, $V_{O,DC}$, DC diode current I_D, and small-signal diode r_d (10 points)

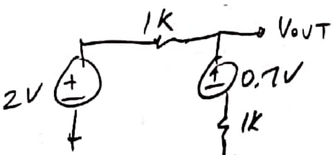
c) Find the small-signal AC transfer function $v_{o,AC}(s)/v_{i,AC}(s)$ (10 points)



DC/ If diode is reverse biased,

$V_{O,DC} = V_b = 2V \Rightarrow$ Not consistent

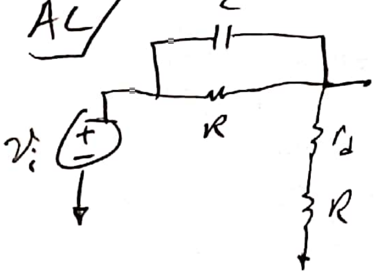
diode must be forward biased



$\frac{V_{OUT} - 2V}{1K} + \frac{V_{OUT} - 0.7V}{1K} = 0 \Rightarrow V_{OUT} = 1.35V$

$I_D = \frac{1.35V - 0.7V}{1k\Omega} = 650\mu A$, $r_d = \frac{V_T}{I_D} = \frac{25.9mV}{650\mu A}$

AC/



$\frac{v_o}{v_i} = \frac{Z_{r_d} + Z_R}{Z_C \| Z_R + Z_{r_d} + Z_R} = \frac{r_d + R}{\frac{1}{sC + 1/R} + r_d + R} = \frac{(sC + \frac{1}{R})(r_d + R)}{1 + sC(r_d + R) + \frac{r_d + R}{R}}$

$\frac{v_o}{v_i} = \frac{s + \frac{1}{RC}}{s + \frac{1}{[R \| (R + r_d)]C}}$

$V_{O,DC}$ = 1.35V

I_D = 650µA

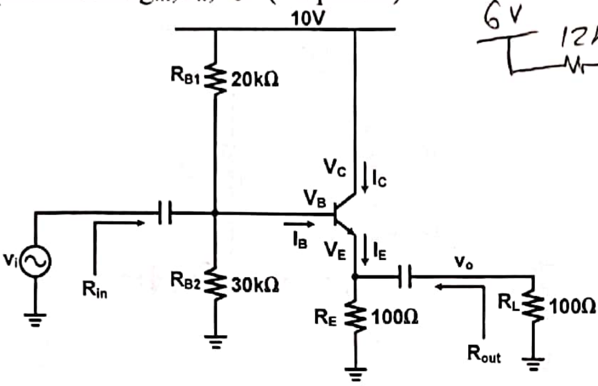
r_d = 39.8Ω

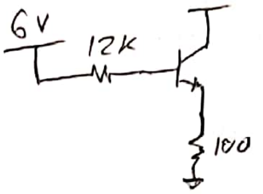
AC Transfer Function: $\frac{s + 100}{s + 196}$

Problem 2 (35 points)

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

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)





$$I_E = \frac{6V - 0.7V}{100 + \frac{12K}{151}} = 29.5mA$$

$$I_B = \frac{I_E}{\beta+1} = 196\mu A$$

$$I_C = \beta I_B = 29.3mA$$

$$V_E = 29.5mA\,(100\Omega) = 2.95V$$

$$V_B = V_E + 0.7V = 3.65V$$

$$g_m = \frac{I_C}{V_T} = \frac{29.3mA}{25.9mV} = 1.13\,A/V$$

$$r_\pi = \frac{V_T}{I_B} = \frac{25.9mV}{196\mu A} = 132\Omega$$

$$r_e = \frac{V_T}{I_E} = \frac{25.9mV}{29.5mA} = 0.88\Omega$$

I_C = 29.3mA

I_B = 196μA

I_E = 29.5mA

V_C = 10V

V_B = 3.65V

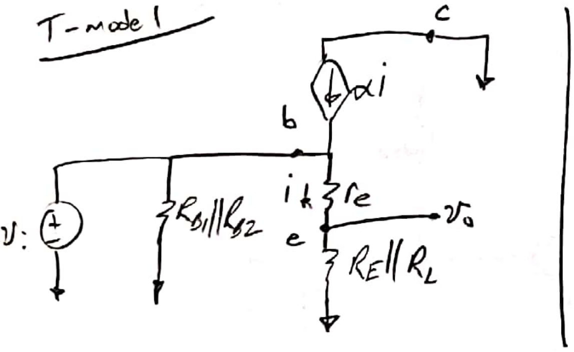
V_E = 2.95V

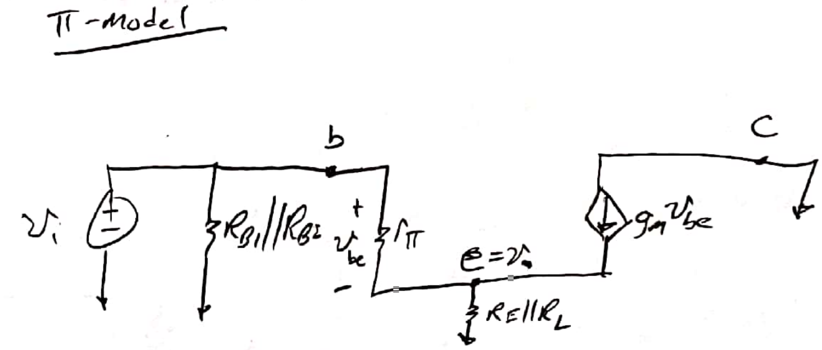
g_m = 1.13 A/V

r_π = 132Ω

r_e = 0.88Ω

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 (can be neglected). (11 points)





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

$$A_V = \frac{R_E \| R_L}{r_e + R_E \| R_L} = \frac{100 \| 100}{0.88 + 100\|100} = 0.983$$

$$R_{in} = R_B \| \left[r_\pi + (\beta+1)(R_E \| R_L)\right] = 12k \| \left[132 + 151(100\|100)\right] = 4.68k\Omega$$

$$R_{OUT} = R_E \| r_e = 100 \| 0.88 = 0.87\Omega$$

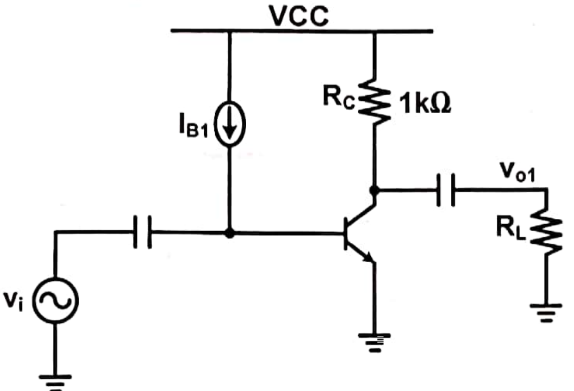
A_v = 0.983

R_{in} = 4.68kΩ

R_{out} = 0.87Ω

Problem 3 (35 points)

a) For the following amplifier, assume the transistor $\beta=150$, $r_o=\infty$, and that the transistor is biased such that $g_m=40mA/V$, $r_e=24.8\Omega$, and $r_\pi=3.8k\Omega$. Calculate the amplifier gain, $A_{v1}=v_{o1}/v_i$, for two load resistor conditions: $R_L=\infty$ and $R_L=16\Omega$. Recall that an ideal current source has infinite output resistance, ie $R_B=\infty$. Assume that the capacitors act as AC shorts. (6 points)



$A_v = -g_m (R_C || R_L)$

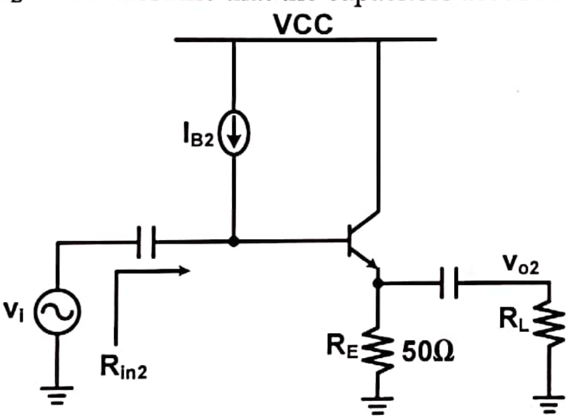
w/ $R_L = \infty \Rightarrow -40^{mA}/_V (1k) = -40\ V/V$

w/ $R_L = 16 \Rightarrow -40^{mA}/_V (1k || 16) = -0.63\ V/V$

A_{v1} ($R_L=\infty$) = -40

A_{v1} ($R_L=16\Omega$) = -0.63

b) For the following amplifier, assume the same transistor bias conditions: $\beta=150$, $r_o=\infty$, and that the transistor is biased such that $g_m=1.93A/V$, $r_e=0.51\Omega$, and $r_\pi=78\Omega$. Calculate the amplifier gain, $A_{v2}=v_{o2}/v_i$, and the input resistance, R_{in2}, for two load resistor conditions: $R_L=\infty$ and $R_L=16\Omega$. Assume that the capacitors act as AC shorts. (14 points)



$A_v = \frac{R_E || R_L}{r_e + R_E || R_L}$

w/ $R_L = \infty \Rightarrow \frac{50}{0.51 + 50} = 0.99\ V/V$

w/ $R_L = 16 \Rightarrow \frac{50 || 16}{0.51 + 50 || 16} = 0.96\ V/V$

A_{v2} ($R_L=\infty$) = 0.99

A_{v2} ($R_L=16\Omega$) = 0.96

R_{in2} ($R_L=\infty$) = 7.63kΩ

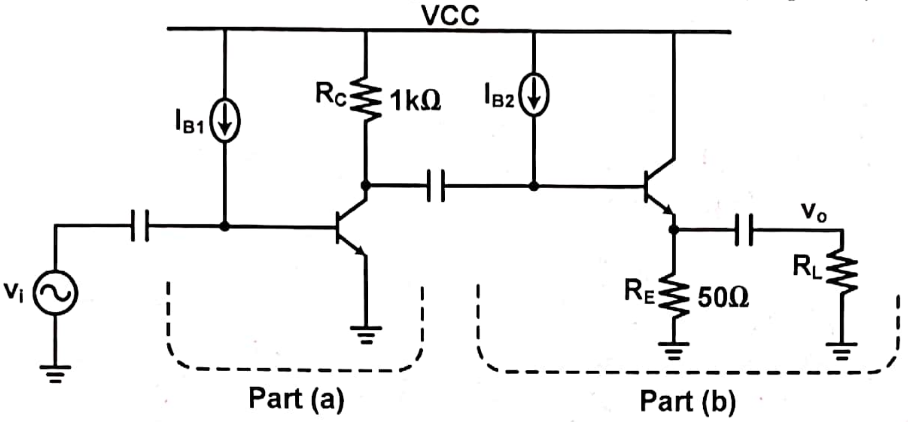
R_{in2} ($R_L=16\Omega$) = 1.91kΩ

$R_{in} = r_\pi + (\beta+1)(R_E || R_L)$

w/ $R_L = \infty \Rightarrow R_{in} = 78 + (151)(50) = 7.63k\Omega$

w/ $R_L = 16 \Rightarrow R_{in} = 78 + (151)(50 || 16) = 1.91k\Omega$

c) The circuit below consists of the amplifier from part (a) cascaded with the amplifier from part (b). Calculate the total 2-stage amplifier gain, $A_v=v_o/v_i$, for two load resistor conditions: $R_L=\infty$ and $R_L=16\Omega$. Assume that the capacitors act as AC shorts. (15 points)



A_v ($R_L=\infty$) = -35.0

A_v ($R_L=16\Omega$) = -25.2

$$\text{Total } A_v = (-g_{m1})(R_c \| R_{in2})\left(\frac{R_E \| R_L}{r_e + R_E \| R_L}\right)$$

$$= -g_{m1}(R_c \| R_{in2}) A_{v2}$$

$$w/ R_L=\infty \Rightarrow -40^{mA}/_V (1k \| 7.63k)(0.99) = -35.0\, ^V/_V$$

$$w/ R_L=16 \Rightarrow -40^{mA}/_V (1k \| 1.91k)(0.96) = -25.2\, ^V/_V$$