Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Spring 2021

Exam #2

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are **5** pages in your exam
- Good Luck!

Problem	Score	Max Score
1		30
2		35
3		35
Total		**100**

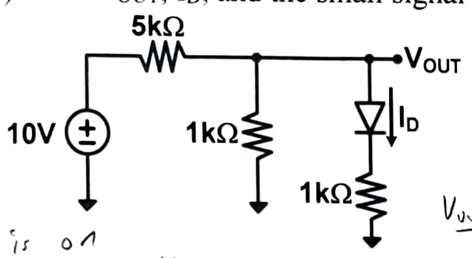
Name: SAM PALERMO

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.

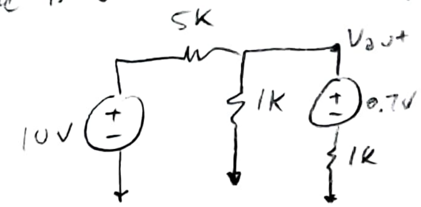
a) Find V_{OUT}, I_D, and the small signal diode resistance, r_d. (10 points)



If diode is off ⇒ $V_{OUT} = 10V\left(\frac{1K}{6K}\right) = 1.67V$

$V_O = 1.67V$; $I_D = 0$ ⇒ not consistent

Diode is on



$$\frac{V_{OUT} - 10V}{5K} + \frac{V_{OUT}}{1K} + \frac{V_{OUT} - 0.7}{1k} = 0$$

$11 V_{OUT} = 13.5V$

$V_{OUT} = 1.23V$

$$I_D = \frac{1.23V - 0.7V}{1K} = 527\mu A$$

$$r_d = \frac{V_T}{I_D} = \frac{25.9mV}{527\mu A}$$

V_{OUT} = 1.23V

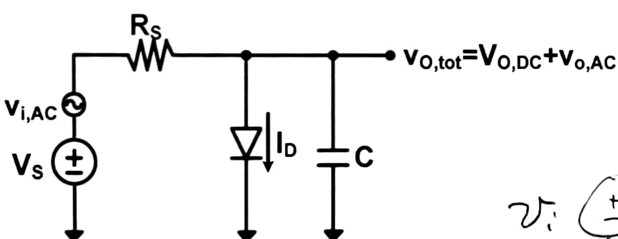
I_D = 527μA

r_d = 49.1Ω

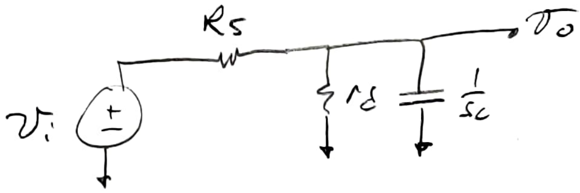
Assume for the following circuit that the **diode is forward biased** and there is a small-signal AC signal, $v_{i,AC}$, in series with a DC voltage.

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

c) Assume that R_S=1kΩ, C=1μF. Calculate the value of I_D and V_S necessary to set the magnitude of the pole frequency of the AC transfer function, $|\omega_p|$, equal to 10krad/s. (10 points)



AC Schematic



$$\frac{v_o}{v_i} = \frac{r_d \parallel \frac{1}{sC}}{R_S + r_d \parallel \frac{1}{sC}} = \frac{\frac{1}{R_S C}}{s + \frac{r_d + R_S}{C r_d R_S}}$$

$$|\omega_p| = \frac{r_d + R_S}{C r_d R_S} = 10krad/s$$

$$\frac{r_d + 1K}{(1\mu F) r_d (1K)} = 10k$$

$r_d + 1k = 10 r_d$

$r_d = 111\Omega$

$$I_D = \frac{V_T}{r_d} = \frac{25.9mV}{111\Omega} = 233\mu A$$

$$\frac{V_S - 0.7V}{1k} = 233\mu A$$

$V_S = 0.933V$

I_D = 233μA

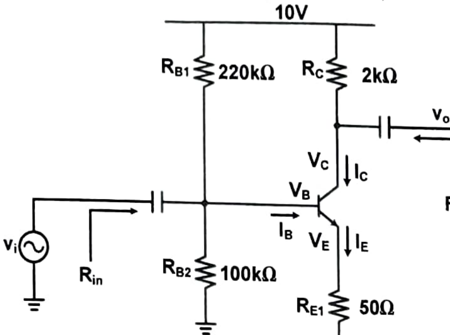
V_S = 0.933V

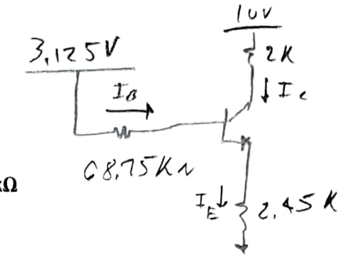
AC Transfer Function:
$$\frac{\frac{1}{R_S C}}{s + \frac{r_d + R_S}{C r_d R_S}}$$

Problem 2 (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)





$I_E = \dfrac{3.125V - 0.7V}{2.45K + \dfrac{68.75K}{151}} = 835\mu A$

$I_B = \dfrac{I_E}{\beta+1} = 5.5\mu A$, $I_C = I_E\left(\dfrac{\beta}{\beta+1}\right) = 829\mu A$

$V_C = 10V - 2K(829\mu A) = 8.34V$

$V_E = 835\mu A(2.45K) = 2.05V$

$V_B = 2.75V$

$g_m = \dfrac{I_C}{V_T} = \dfrac{829\mu A}{25.9mV} = 32\,mA/V$

$r_e = \dfrac{V_T}{I_E} = \dfrac{25.9mV}{835\mu A} = 31\Omega$

$r_\pi = \dfrac{V_T}{I_B} = \dfrac{25.9mV}{5.5\mu A} = 4.71K\Omega$

$I_C =$ 829μA

$I_B =$ 5.5μA

$I_E =$ 835μA

$V_C =$ 8.34V

$V_B =$ 2.75V

$V_E =$ 2.05V

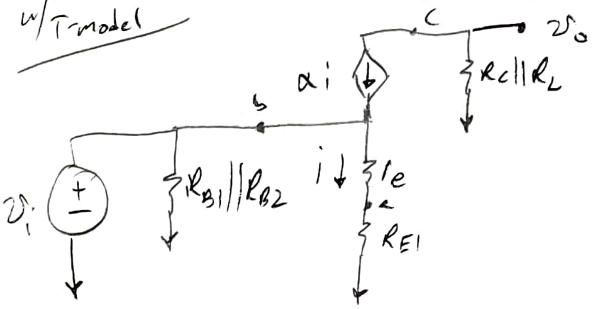
$g_m =$ 32 mA/V

$r_\pi =$ 4.71KΩ

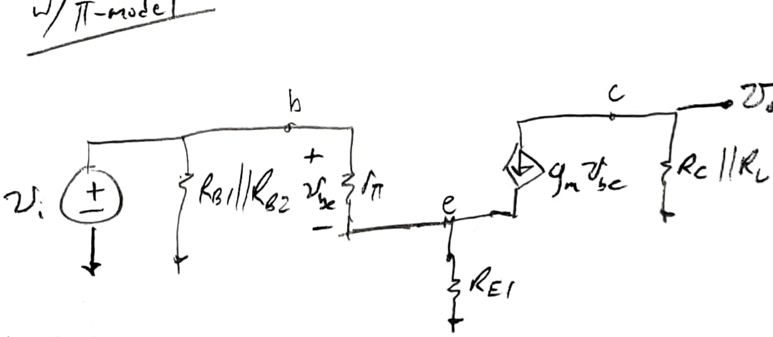
$r_e =$ 31Ω

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)

w/ T-model



w/ π-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)

$A_v = \dfrac{-g_m(R_C||R_L)}{1 + \dfrac{g_m R_{E1}}{\alpha}} = -\dfrac{(32mA/V)(2K||10K)}{1 + \dfrac{32mA/V(50)}{0.993}} = -20.4\,V/V$

$A_v =$ −20.4 V/V

$R_{in} = R_B||\left[r_\pi + (\beta+1)R_{E1}\right] = 68.75k||\left[4.71k + 151(50)\right] = 10.4K$

$R_{in} =$ 10.4KΩ

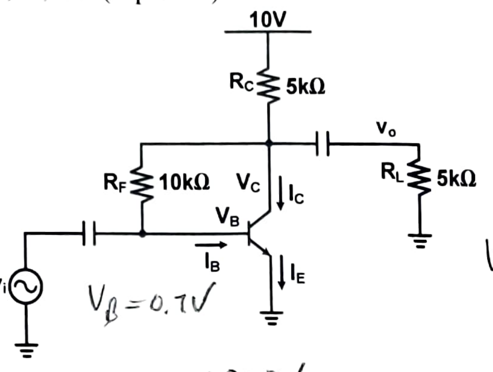
$R_{out} = R_C = 2K$

$R_{out} =$ 2KΩ

Problem 3 (35 points)

Assume for Problem 3 that the transistor β=150, V_{BE}=0.7V, and V_{th}=25.9mV.

a) Calculate the DC values for V_C, V_B, I_C, I_B, and I_E. Compute the AC small signal parameters g_m, r_π, r_e. (8 points)



KCL @ V_c

$$\frac{V_c-10}{5k} + \frac{V_c-0.7}{10k}(\beta+1) = 0$$

$$V_c(\beta+3) = 20 + 0.7(\beta+1)$$

$$V_c = \frac{20+0.7(151)}{153}$$

$$V_c = 0.822V$$

$$I_E = I_B + I_C = \frac{10V - 0.822V}{5k} = 1.84mA$$

$$I_B = \frac{I_E}{\beta+1} = \frac{1.84mA}{151} = 12.2\mu A, \quad I_C = \beta I_B = 1.82mA$$

$$r_\pi = \frac{V_T}{I_B} = \frac{25.9mV}{12.2\mu A} = 2.12k\Omega$$

$$g_m = \frac{I_C}{V_T} = \frac{1.82mA}{25.9mV} = 70.4 \, mA/V$$

$$r_e = \frac{V_T}{I_E} = \frac{25.9mV}{1.84mA} = 14.1\Omega$$

I_C = 1.82mA

I_B = 12.2μA

I_E = 1.84mA

V_C = 0.822V

V_B = 0.7V

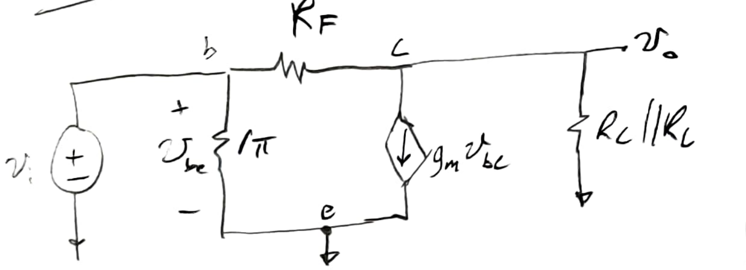
g_m = 70.4 mA/V

r_π = 2.12kΩ

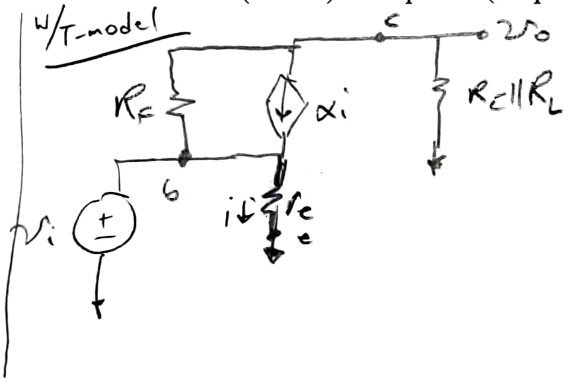
r_e = 14.1Ω

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 (15 points)

w/ π-model



w/ T-model



c) Using the small-signal model in (b), derive an expression for the small signal gain $A_v=v_o/v_i$ in terms of R_F, R_C, R_L and the transistor small signal parameters (variables only, no numbers). Then compute A_v with the parameters from part (a). (12 points)

Using π-model

KCL @ v_o:

$$\frac{v_o - v_i}{R_F} + g_m v_i + \frac{v_o}{R_C||R_L} = 0$$

$$v_o\left[\frac{1}{R_F} + \frac{1}{R_C||R_L}\right] = -v_i\left[g_m - \frac{1}{R_F}\right]$$

A_v Expression: $$\frac{v_o}{v_i} = -\left[g_m - \frac{1}{R_F}\right]\left(R_F || R_C || R_L\right)$$

A_v = −141 V/V

$$= -\left[70.4m - \frac{1}{10k}\right]\left(10k || 5k || 5k\right) = -141 \, V/V$$