① a) Diode is off $\Rightarrow V_{diode} < 0.7V$, $I_{diode} = 0$

$\therefore V_o < V_{in} + 0.7$

from graph : $V_o = 2V_{in} - 1$

$2V_{in} - 1 < V_{in} + 0.7$

$\Rightarrow V_{in} < 1.7V$ or $V_{DC} < 1.7V$

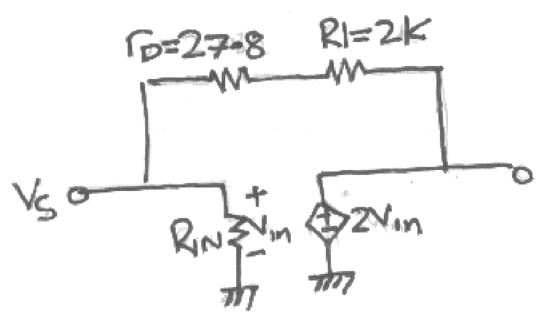
b) $V_{DC} = 2.5V \Rightarrow V_{OUT} = 4V$

$V_R = V_O - V_{DC} - V_{diode}$

$= 4 - 2.5 - 0.7 = 0.8V$

$R = \frac{V_R}{I_R} = \frac{0.8}{2m} = 400\Omega$

c) $r_D = \frac{nV_T}{I_D} = \frac{25m}{0.9m} = 27.8\Omega$



d) $i_D = \frac{V_{OUT} - V_{in}}{2k + 27.8} = \frac{2V_S - V_S}{2.0278k} = 0.493\,mA$

$$I = (0.9 + 0.493\ V_s)\,mA$$

DC AC

e) For amplifier clipping:

$V_{in} = 3.5V$

$(V_1)_{max} = 5 - 3.5 = 1.5V$

For linear operation of diode:

$V_d < 10mV$

$i_d < \frac{10m}{r_D} = \frac{10m}{27.8} = 0.3597\ mA$

from (d):

$0.493\ V_1 \sin\omega t < 0.3597$

$\Rightarrow (V_1)_{max} = 0.729\ V$

∴ limiting condition is diode linear operation limit

$\Rightarrow (V_1)_{max} = 0.729\ V$

#2

(a) $$v_- = \frac{R_3}{R_3+R_S} v_S$$

$$i_{R2} = \left(\frac{v_-}{R_1} + \frac{v_- - v_S}{R_4}\right)$$

$$v_{o1} = \left(\frac{v_-}{R_1} + \frac{v_- - v_S}{R_4}\right) R_2 + v_-$$

$$= \frac{R_3 R_2 v_S}{R_1(R_3+R_S)} + \frac{R_3 R_2 v_S}{R_4(R_3+R_S)}) - \frac{R_2}{R_4} v_S + \frac{R_3}{R_3+R_S} v_S$$

$$\Rightarrow \boxed{\frac{v_{o1}}{v_s} = -19.59 \text{ V/V}}$$

(b) By inspection: $\boxed{R_{in} = R_6 \,//\, (R_S + R_3)}$

#2

(c)

$$v_+ = \frac{R_{10}}{R_{10}+R_7} v_{o2}$$

$$v_{o2} = \frac{\frac{R_{10}}{R_{10}+R_7} v_{o2} - v_{o1}}{R_9} R_8 + \frac{R_{10}}{R_{10}+R_7} v_{o2}$$

$$v_{o2}\left[1 - \frac{R_{10}}{R_{10}+R_7}\left(\frac{R_8}{R_9} + 1\right)\right] = v_{o1}\left[-\frac{R8}{R9}\right]$$

$$\Rightarrow \boxed{\frac{v_{o2}}{v_{o1}} = 2.02 \frac{V}{V}}$$

(d)

$$\frac{v_{o2}}{v} = \frac{v_{o2}}{v} \times \frac{v_{o1}}{v} = \boxed{-39.57 \text{ V/V}}$$

(e)

$$v_{o2} = \frac{-v_{o2}}{A} + \frac{-v_{o2}/A - v_{o1}}{R_9} R8$$

$$\Rightarrow v_{o2}\left[1 + \frac{1}{A} + \frac{R8}{AR_9}\right] = -v_{o1}\frac{R8}{R9}$$

$$\Rightarrow \frac{v_{o2}}{v_{o1}} = \frac{-R8/R9}{1 + \frac{1}{A} + \frac{R8/R9}{A}} = \boxed{-49.75}$$

③a) $V_0 = -1.25V$

$V_{D4} = -0.75V$

$I_{D4} = 5m\, e^{\frac{0.05}{2\times25m}}$

$= 13.6mA$

$\therefore$ at node above 99Ω resistance, $V = V_0 + 99(13.6m)$

$= 0.0955V$

$V_2 = V_1 + nV_T \ln\left(\frac{I_2}{I_1}\right)$

$I_2 = I_1 e^{\frac{V_2 - V_1}{nV_T}}$

$V_{D1} = V_{D2} = V_{D3} = \frac{0.0955-(-2)}{3} = 0.6985V$

$I_{D1} = I_{D2} = I_{D3} = 5m\, e^{\frac{-1.48\times10^{-3}}{50m}}$

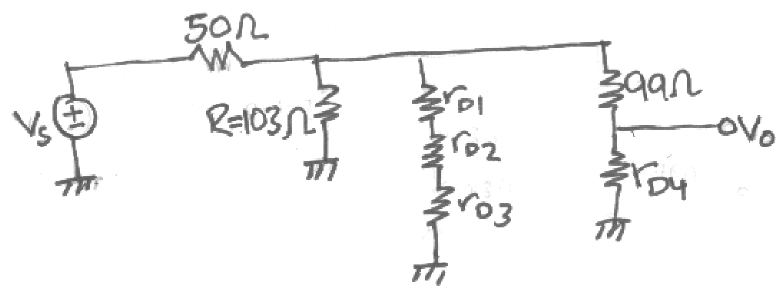
$= 4.854mA$

$I_R = 4.854m + 13.6mA = 18.45\ mA$

$R = \frac{V}{I_R} = \frac{2-0.0955}{18.45m} = 103.2\Omega$

b) $r_{D1} = r_{D2} = r_{D3} = \frac{nV_T}{I_D} = \frac{2\times25m}{4.85m} = 10.3\Omega$

$r_{D4} = 3.676\Omega$



c) $\frac{V_o}{V_s} = \frac{R_{eq}}{R_{eq}+50} \times \frac{3.676}{99+3.676}$

$R_{eq} = (103.2) \| (3 \times 10^3) \| (99+3.676) = 19.3\Omega$

$\frac{V_o}{V_s} = 9.974 \text{ mV/V}$

d) $R_{in} = 50 + R_{eq} = 69.3\Omega$

(4) a) $\beta = \infty \Rightarrow I_B = 0$; $I_C = I_E$

$$V_B = \frac{100}{100+220} \times 8 = 2.5V$$

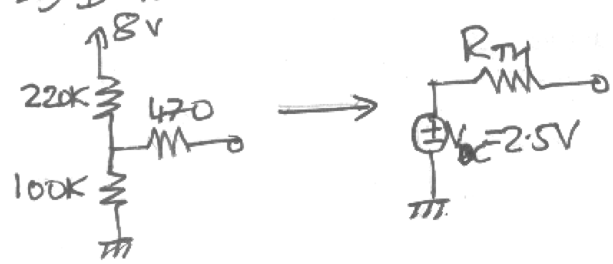
If $V_{BE} = 0.7V$; $V_E = 1.8V$

$$I_E = \frac{V_E}{1K} = 1.8mA = I_C$$

$$V_C = 8 - I_C R_C = 8 - 7.2 = 0.8V$$

$\therefore V_C < V_B \Rightarrow$ NOT in active mode

b) $\beta = 100$



$V_{oc} = 2.5V$ (from a)

$R_{TH} = 470 + 220K \| 100K$
$= 69.22k\Omega$

By KVL: $2.5 - I_B R_B - 0.7 - I_E R_E = 0$; $I_E = (\beta+1) I_B$

$1.8 - I_B(69.22k) - (101) I_B \, 1K = 0$

$I_B = 10.6 \mu A$

$I_C = \beta I_B = 1.06 mA$

$I_E = (\beta+1) I_B = 1.07 mA$

$V_B = 2.5 - I_B R_B = 1.768V$

$V_E = V_B - 0.7 = 1.068V$

$V_C = 8 - I_C R_C = 4.827V$

Also:

$V_C > V_B$
$\Rightarrow$ active mode