Final Practice

Problem 2

Use:

$$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_4 = 5$$

$$\left(\frac{W}{L}\right)_3 = 200$$

V_t=1V

k_n'=40μA/V^2

$\lambda_{1,2,3,4}$**=0**

V_{D0}=0.6

n=1

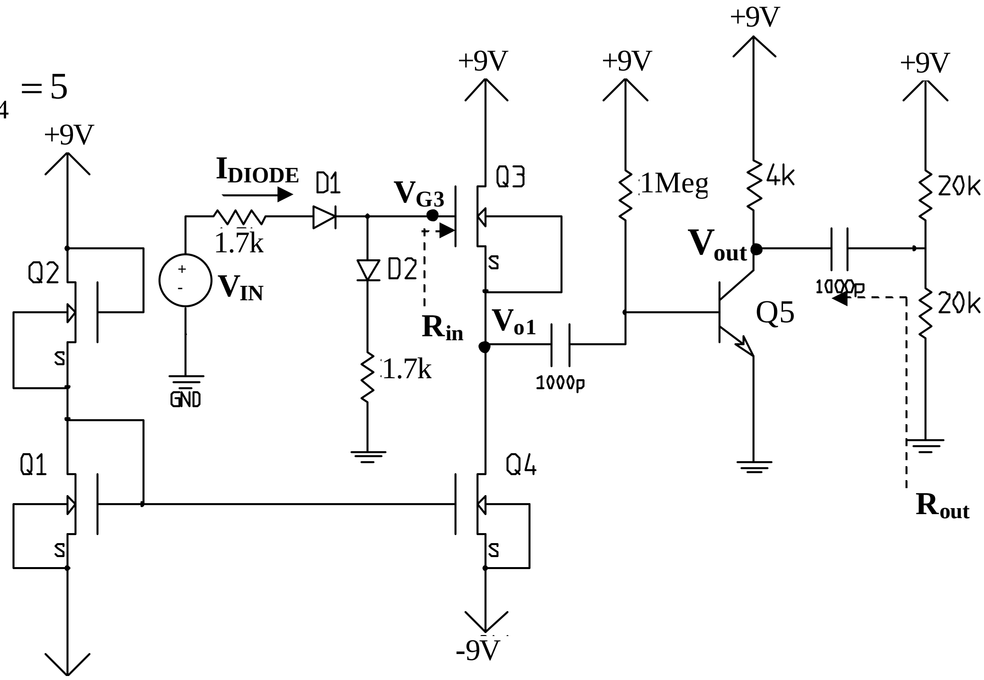
V_T=25mV

ignore V_A

V_{BE}=0.7

β**=150**

V_{in}=8+1msinωt



1. Find the following DC values.
   (a) I_{DIODE}
   (b) V_{G3}
   (c) V_{o1}
   (d) V_{out}

2. Draw the AC small-signal circuit

3. Find the AC values:

   (a) Find R_{in}.

   (b) Find R_{out}.

   (c) Find the overall gain, Vo/V_{IN}. State value as a numeric value.

4. What is the maximum value that the resistor R_C = 4k at the collector of transistor Q5 be changed to and still keep the transistor active? Explain in detail how this resistor changes the overall gain?

Problem 3

Use: $V_t = 1V$ $k_n' = 30\mu A/V^2$

$\lambda = 0$

$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right)_3 = 10$

$\left(\frac{W}{L}\right)_4 = 100$

$V_{D0} = 0.6$

$n = 2$

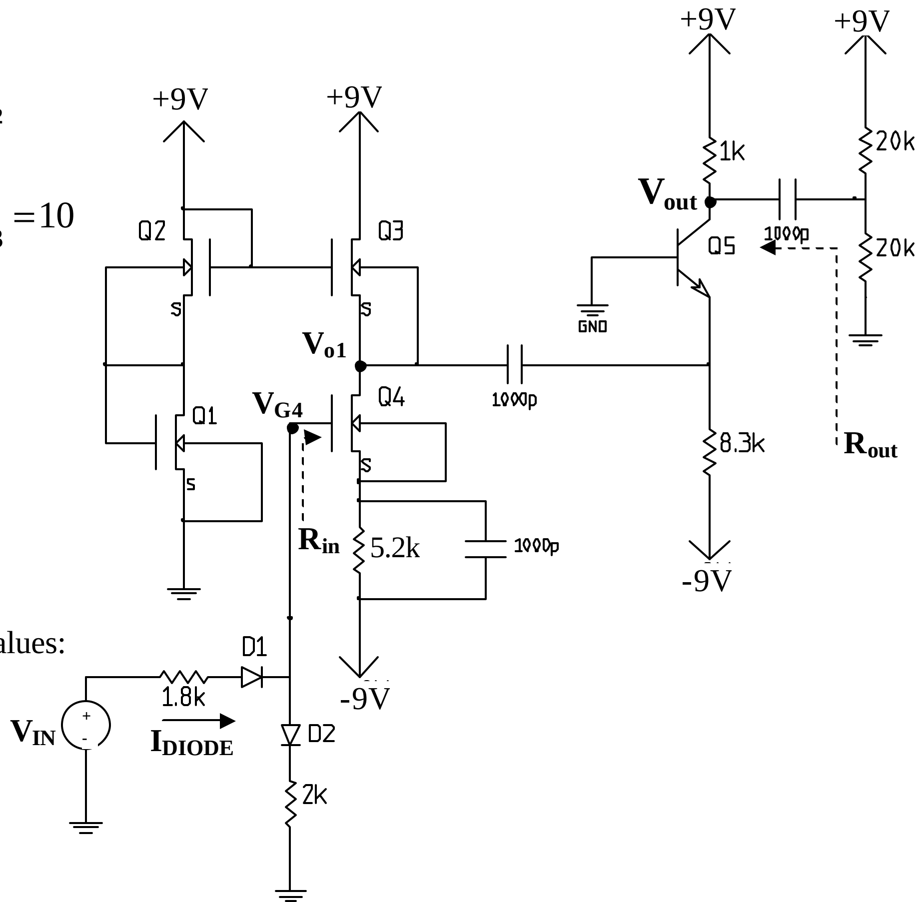
$V_T = 25mV$

ignore V_A

$V_{BE} = 0.7$

$\beta = 150$

$V_{in} = 5 + 2m\sin\omega t$



1. Find the following DC values:
   (e) I_{DIODE}
   (f) V_{G4}
   (g) V_{o1}
   (h) V_{out}

2. Draw the AC small-signal circuit

3. Find the AC parameters:
   (a) r_π
   (b) g_m for transistor Q4
   (c) g_m for transistor Q5
   (d) r_d for the diodes

4. Find the values for R_{in} and R_{out}.

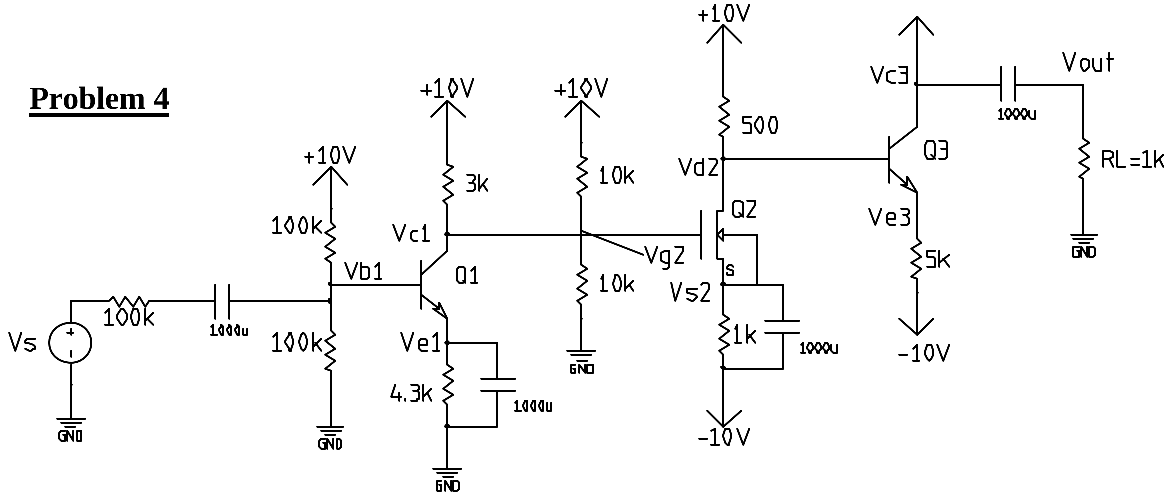
5. Find the gain: $\left(\frac{V_{o1}}{V_{IN}}\right)$

6. Find the gain: $\left(\frac{V_{out}}{V_{IN}}\right)$

7. Find the total instantaneous output voltage V_{out}. Draw the input, V_I, and the total output (DC and AC) on the same graph vs time for 2 periods. Mark the maximum and minimum peak values.

8. What is the maximum value that the resistor R_C=1k at the collector of transistor Q5 be changed to and still keep the transistor in saturation? Explain in detail how this resistor changes the overall gain?

Problem 4



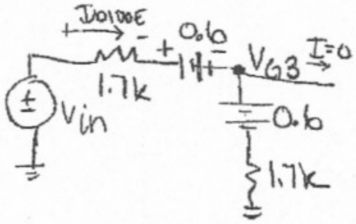
Solve the circuit when n=1, V_T=25mV, V_t=+1V, k'(W/L)=2mA/V^2, β=100, ignore V_A, λ=0, V_{BE}=0.7V

a. DC Values:
   i. I_{B1}, I_{C1}, I_{E1}
   ii. I_{D2}, I_{G2}, I_{S2}
   iii. I_{B3}, I_{C3}, I_{E3}
   iv. V_{B1}, V_{E1}, V_{C1}
   v. V_{G2}, V_{S2}, V_{D2}
   vi. V_{B3}, V_{E3}, V_{C3}

b. AC Values:
   i. R_{in} (do not include 100k)
   ii. R_{out} (do not include RL)
   iii. Gain: V_{out}/Vs

(#2)

1. (a) I_{DIODE} :



$-V_{in} + I_{DIODE}(1.7k + 1.7k) + 0.6 + 0.6 = 0$

$V_{in-DC} = 8V$

$I_{DIODE} = \frac{V_{IN} - 1.2}{3400} = \boxed{2mA}$

(b) $V_{G3} \Rightarrow$ $-V_{G3} + 0.6 + I_{DIODE}(1.7k) = 0$

$V_{G3} = \boxed{4V}$

(c) $V_{o1} \Rightarrow$

$\frac{1}{2} K_n'\left(\frac{W}{L}\right)(V_{GS_2} - V_{tn})^2 = \frac{1}{2} K_n'\left(\frac{W}{L}\right)(V_{GS_1} - V_{tn})^2$

$(9 - V_s - 1)^2 = (V_s + 9 - 1)^2$

$V_s = 0$

$I_4 = \frac{1}{2}(40\mu)(5)(9 - 0 - 1)^2 = 6.4m$

$I_3 = I_4 = 6.4m = \frac{1}{2}(40\mu)(200)(4 - V_{o1} - 1)^2$

$0 = -1.6 + 9 - 6V_{o1} + V_{o1}^2$

$0 = V_{o1}^2 - 6V_{o1} + 7.4$

$V_{o1} = \frac{+6 \pm \sqrt{36 - 4(7.4)(1)}}{2} = 4.25, \boxed{1.75}$

$V_{GS} = 4 - 1.75 = 2.25V$

$V_{GS} = 4 - 4.25 = -.25 < V_t$ ✗ NO

(d) $V_{out} = 9 - I_c(4k) = \boxed{4.02}$

$-9 + I_B(1Meg) + 0.7 = 0$

$I_B = \frac{9 - 0.7}{Meg} = 8.3\mu$

$I_c = \beta I_B = 1.245m$

(#2)

2.

$$r_{d1} = r_{d2} = \frac{nV_T}{I_D} = \frac{(1)(25m)}{2m} = 12.5\,\Omega$$

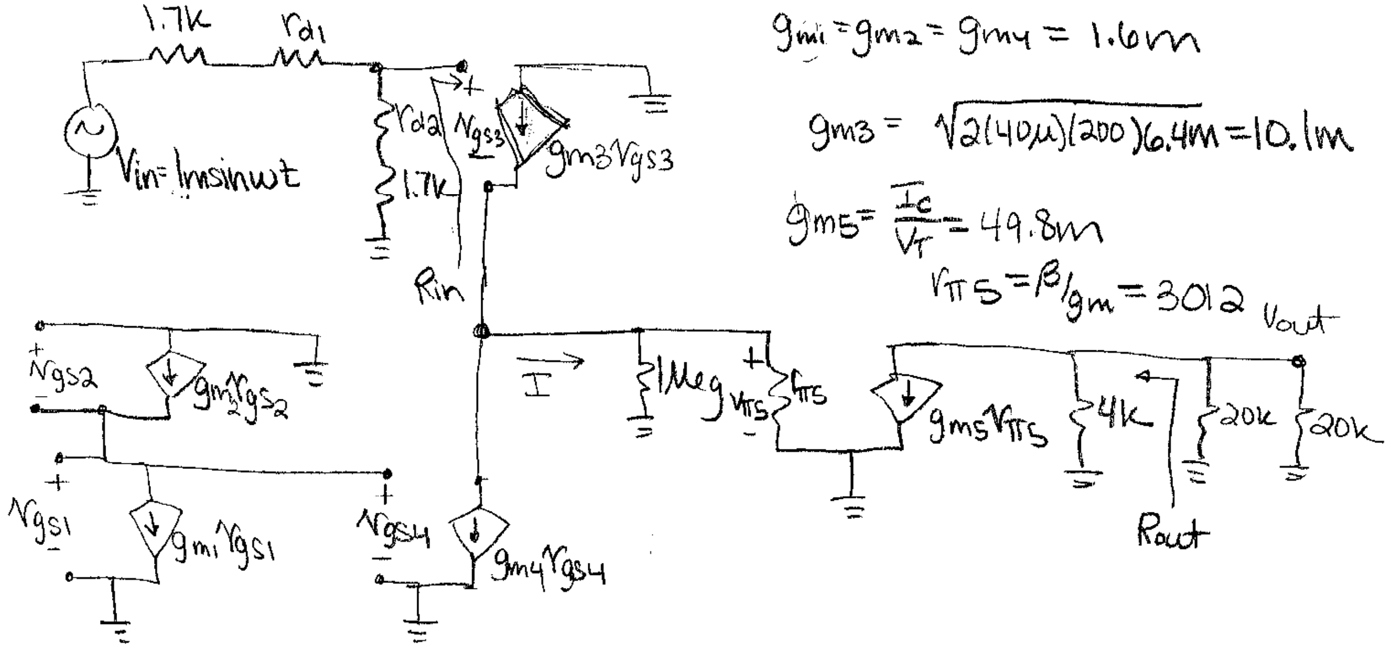
$$g_{m1} = g_{m2} = g_{m4} = \sqrt{2k_n'(\tfrac{W}{L})I_D} = \sqrt{2(40\mu)(5)6.4m}$$

$$g_{m1} = g_{m2} = g_{m4} = 1.6m$$

$$g_{m3} = \sqrt{2(40\mu)(200)6.4m} = 10.1m$$

$$g_{m5} = \frac{I_C}{V_T} = 49.8m$$

$$r_{\pi5} = \beta/g_m = 3012$$



3. (a) $R_{in} = \infty$

(b) $R_{out} = 4k$

(c) $\frac{V_{out}}{V_{in}} \Rightarrow V_{out} = -g_{m5}v_{\pi5}(4k \| 10k)$

$$V_{\pi5} = I\,(1Meg \| r_{\pi5})$$

$$g_{m3}v_{gs3} - I - g_{m4}v_{gs4} = 0$$

$$I = g_{m3}v_{gs3} - g_{m4}v_{gs4}$$

$V_{G4} = 0$, $V_{S4} = 0 \Rightarrow v_{gs4} = 0$

$V_{G3} = \frac{1}{2}V_{IN}$, $V_{S3} = V_{\pi5}$

$$V_{\pi5} = g_{m3}(\tfrac{1}{2}V_{IN} - V_{\pi5})(1M \| r_{\pi5}) \Rightarrow V_{\pi5} = \frac{g_{m3}V_{IN}(1Meg \| r_{\pi5})}{2(1 + g_{m3}(1Meg \| r_{\pi5}))}$$

$$V_{out} = \frac{-g_{m5}g_{m3}\overbrace{(1Meg \| r_{\pi5})}^{3003}\overbrace{(4k \| 10k)}^{2857}}{2(1 + g_{m3}(1Meg \| r_{\pi5}))} = \boxed{-69\ V/V}$$

#2

4. $V_C = V_B$ is the point of transition between active and saturation.

$V_C > V_B > V_E \Rightarrow$ active

$V_C < V_B > V_E \Rightarrow$ Saturation

$V_B = 0.7 = V_C$

$V_C = 9 - I_C R_C$

$0.7 = 9 - (1.245m) R_C$

$R_C = \frac{9 - 0.7}{1.245m} = \boxed{6.67\ K}$

[3]

#1. I_{DIODE} : $(V_{DO} = 0.6)$ V_{IN} (DC) $= 5V$

$$-V_{IN} + I_{DIODE}(1.8k + 2k) + 0.6 + 0.6 = 0$$

$$I_{DIODE} = \frac{5 - 1.2}{3.8k} = \boxed{1mA}$$

$$V_{G4} = +0.6 + I_{DIODE}(2K) = \boxed{2.6V}$$

$V_{o1} \Rightarrow$ Q_1 and Q_2 are equal so $V_{S2} = 4.5V$

$$I_2 = I_1 = \frac{1}{2}(30\mu)(10)(9 - 4.5 - 1)^2 = 1.8m$$

Q_3 : $V_G = V_D$ is the point between sat/triode

$$I_4 = \frac{1}{2}(30\mu)(100)(2.6 - I_4(5.2k) + 9 - 1)^2$$

gives $I_4 = 0.182e^{-2}$, $0.23e^{-2}$

$V_{GS} = 2.1$ $V_{GS} = -0.36$ X off

$$I_4 = I_3 = 1.82m = \frac{1}{2}(30\mu)(10)(9 - V_{o1} - 1)^2$$

$$V_{o1} = \boxed{4.5V}$$

$$V_{out} = 9 - I_C(1K)$$

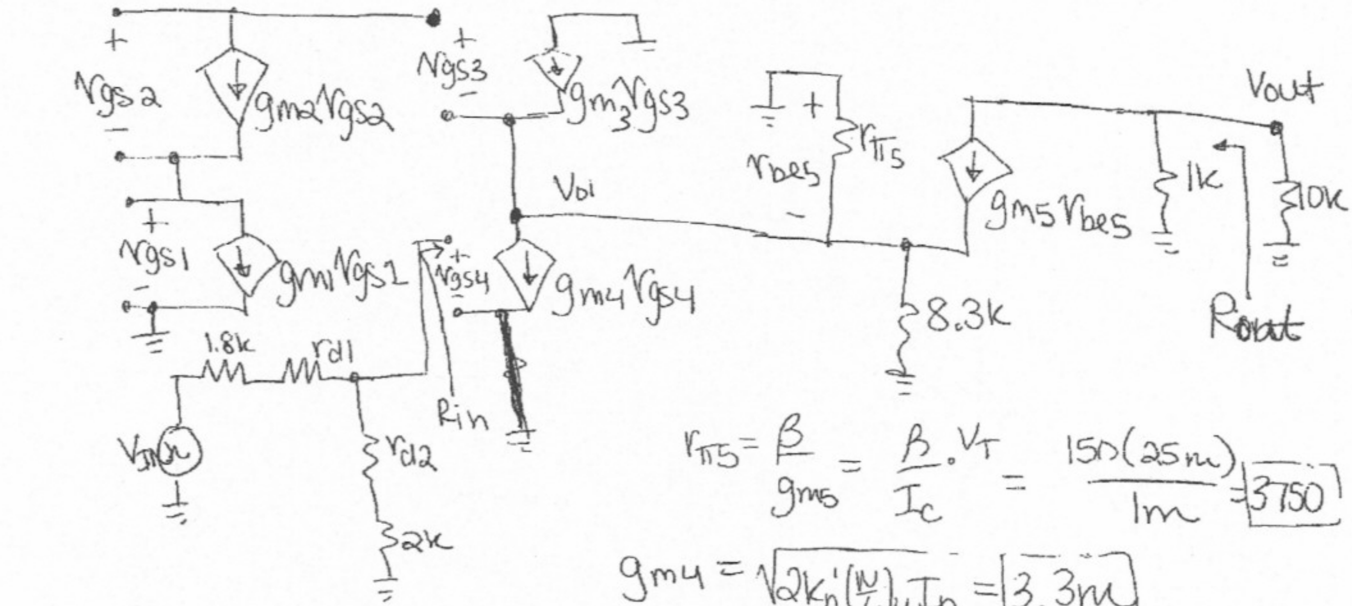
$$0 + 0.7 + I_E(8.3K) - 9 = 0$$

$$I_E = \frac{8.3}{8.3k} = 1m$$

$$I_C = \alpha I_E = 0.99m$$

$$V_{out} = \boxed{8.01V}$$

#3.



$$r_{\pi 5} = \frac{\beta}{g_{m5}} = \frac{\beta \cdot V_T}{I_C} = \frac{150(25m)}{1m} = \boxed{3750}$$

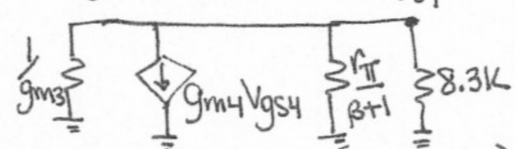
$$g_{m4} = \sqrt{2k_n'\left(\tfrac{W}{L}\right)_4 I_D} = \boxed{3.3m}$$

$$r_{d1} = r_{d2} = \frac{nV_T}{I_D} = \frac{2(25m)}{1m} = \boxed{50\Omega}$$

$$g_{m5} = \frac{I_C}{V_T} = \frac{1m}{25m} = \boxed{0.04}$$

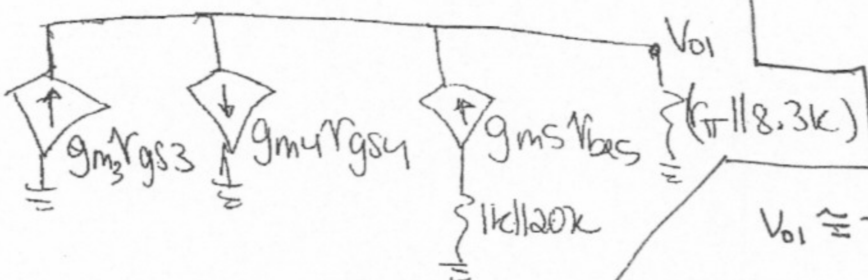
$\boxed{R_{in} = \infty}$ $\boxed{R_{out} = 1k}$

OR $V_{gs3} = -V_{o1}$ so
· reflect $g_{m5}V_{be5}$



$$V_{o1} = -g_{m4}V_{gs4}\left(\frac{r_\pi}{\beta+1} \,\|\, 8.3K \,\|\, \frac{1}{g_{m3}}\right)$$

$V_{o1} \cong -0.04\,V_{IN}$ (SAME)



$$(g_{m3}V_{gs3} - g_{m4}V_{gs4} + g_{m5}V_{be5})(r_\pi \| 8.3k) = V_{o1}$$

$V_{g3} = 0$, $V_{s3} = V_{o1}$

$$V_{g4} = \frac{V_{IN}(r_{d2} + 2k)}{1.8k + 2k + 2r_d} = 0.5V_{IN}$$

$V_{be5} = -V_{o1}$

$$[-g_{m3}V_{o1} - g_{m4}(0.5V_{IN}) + g_{m5}(-V_{o1})](2583) = V_{o1}$$

$$V_{o1} = -g_{m4}(0.5)(2583)V_{IN} \Big/ 1 + (g_{m3} + g_{m5})2583$$

#3.

$$\frac{V_{o1}}{V_{IN}} = \sout{4.3V/5mA} \quad \frac{-g_{m4}(0.5)2583}{1+(g_{m3}+g_{m5})2583}$$

$$\frac{V_{o1}}{V_{IN}} = \frac{-4.3}{(1+(1m+0.04)2583)} = -0.04$$

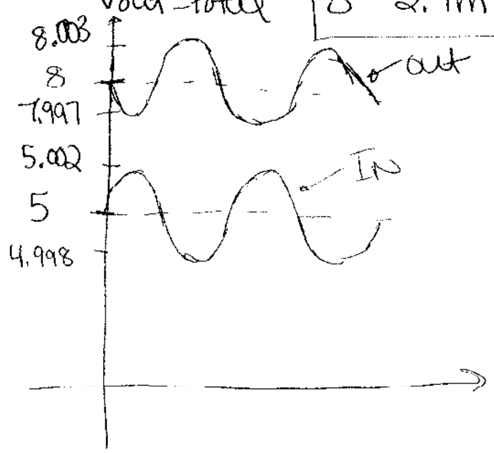
$$\frac{V_{out}}{V_{o1}} \Rightarrow -g_{m5} V_{be5} (1k \parallel 10k) = -g_{m5}(-V_{o1})(909) = V_o$$

$$\frac{V_{out}}{V_{o1}} = 36.36$$

$$\frac{V_{out}}{V_{IN}} = \frac{V_{o1}}{V_{IN}} \cdot \frac{V_{out}}{V_{o1}} = 36.36(-0.04) = \boxed{-1.45}$$

$$V_{out} = -1.45(2m \sin \omega t) = -2.9m \sin(\omega t)$$

$$V_{out\_total} = \boxed{8 - 2.9m \sin(\omega t)}$$



#3

frequency dependence:

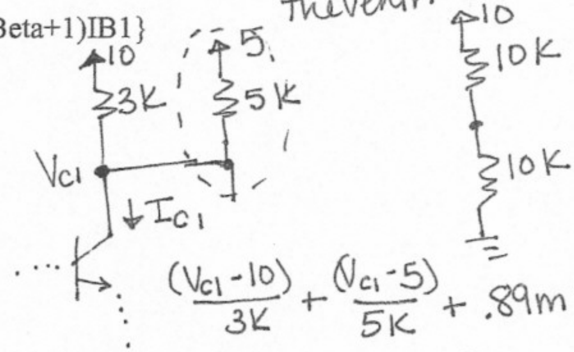
- $C_{s4} \Rightarrow \dfrac{1}{C_{s4}(\frac{1}{g_{m4}} \| 5.2k)} = \dfrac{1}{1000p(\frac{1}{3.3m} \| 5.2k)} =$ 3.5Meg $\frac{rad}{sec}$.
- $C_{s3} \Rightarrow \dfrac{1}{C_{s3}(\frac{1}{g_{m3}} + r_{\pi 5} \| 8.3k \| \frac{1}{g_{m5}})} = \dfrac{1}{1000p(\frac{1}{1m} + 3750 \| 8.3k \| \frac{1}{0.04})}$
  $= 976k$ rad/sec.
- $C_{s3} \Rightarrow \dfrac{1}{C_{s3}(1k + 10k)} = 91k$ $\frac{rad}{sec}$.

#4

Thevenin equivalent at base of Q1: 5V = Vth and Rth=50k. The loop gives

-5 + IB1(50k) + VBE+IE1(4.3k) = 0 {IE1=(Beta+1)IB1}

V_{C1} :



IB1=4.3/(50k+434k) = 8.9µ
IE1 = 101*8.9u = .899m
IC1=Beta * IB1 = .89m

VB1=5-IB1(50k) = 4.6V
VE1 = IE1(4.3k) = 3.9V

$\frac{(V_{C1} - 10)}{3K} + \frac{(V_{C1} - 5)}{5K} + .89m = 0$

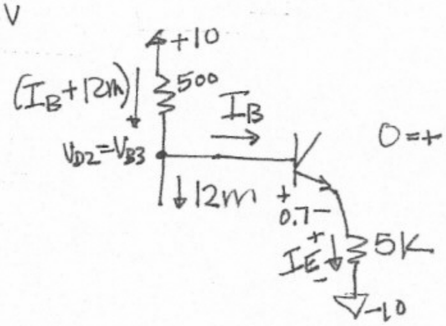
$V_{C1} = 6.46V$

6.46V > 4.6V > 3.9V ✓ ACTIVE

Q2: VG2=VC1 = 6.5
Vs=ID2(1k) – 10 => ID2=1/2k'(W/L)(VGS-Vt)²=1/2k'(W/L)(6.5 - ID2(1k)+10-1)² => I_{D2} = 12m, 20m
ID2= 12m =>
$V_{D2} = V_{B3} = 10 - (12.03m)500 \cong 4V$

NOT SAT × 4 < (6.5−1)

$V_S = 10$
$V_{GS} = -3.5 < V_t$
× NO



Q3: VB3=VD2= 4

$0 = +10 - (I_B + 12m)500 - 0.7 - I_E(5k) + 10$

Ic= 2.63m

$I_E = 2.66m$
$I_B = 26.3\mu$

VE=IE3(5k)-10=3.3V
Vc=10V
Sat => {10> 4>3.3}

(b)
Rin=2809 ohm, Rout=infinity, Non linear gain due to Q2 Not being saturated