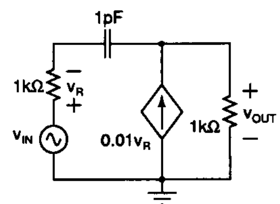
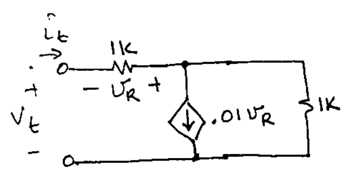
NAME: STUDENT NO.:

University of Puerto Rico
Electrical and Computer Engineering Department
INEL 4202 - Electronics II - Spring 2000 - Exam 2 - Prof. M. Toledo
THERE ARE FOUR PROBLEMS - BE CLEAR OR LOOSE POINTS
#4 is a bonus problem. Exam is 85 pts. in total (+bonus)

1. Use the open-circuit time constant method to estimate the high-frequency pole for the following circuit. Do not use the Miller approximation. (25 pts)



Shortening the source, the cap "sees" the following circuit



Applying a test source and KVL on the external loop gives

$$V_t = i_t(1K) + [i_t - (.01)v_R]1K$$

$$v_R = -i_t(1K)$$

$$\therefore \quad \frac{V_t}{i_t} = 1k + [1 + (.01)(1k)]1k = 12k$$

$$\omega_H = \frac{1}{1pF \times 12k\Omega} = \boxed{8.3 \times 10^7 \text{ rps}}$$

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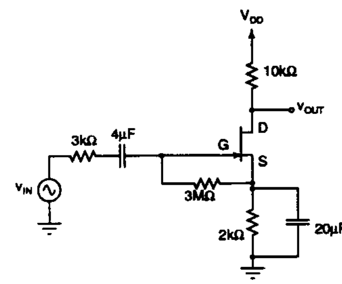
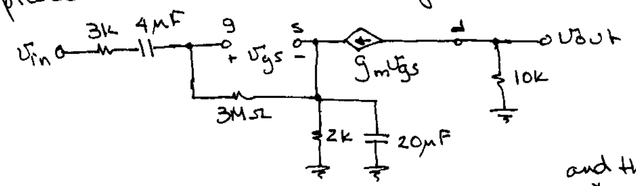
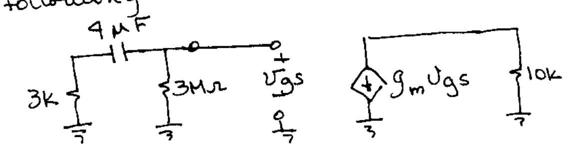
2. Use the short circuit time constant method to estimate the dominant low-frequency pole for the circuit below. The transistor has $g_m = 5.6 \times 10^{-3}$ A/V. (25 pts)



Replace FET with low-freq. model to get

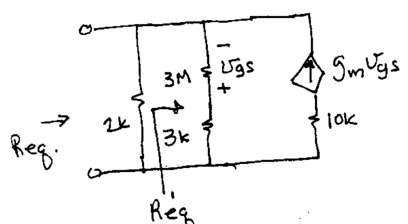


⟹ 1^{st} consider the 4μF cap. Short the 20μF and the independent source to obtain the following circuit

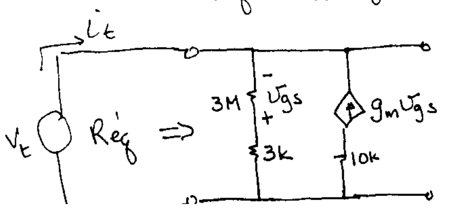


∴ 4μF "sees" 3003kΩ and $\omega_{L_1} = \dfrac{1}{4\mu F(3003k)} = \boxed{.08 \text{ rps}}$

⟹ Now let's look at the 20μF cap.



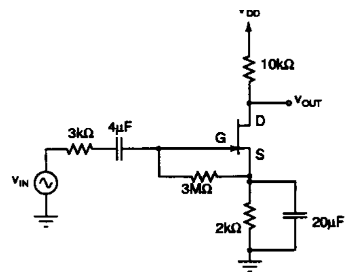
$R_{eq} = 2k \| R_{eq}'$



$$v_{gs} = -\frac{3M}{3003k} V_t$$

$$\therefore \; i_t = \frac{V_t}{3003k} - g_m v_{gs}$$

$$= V_t\left(\frac{1}{3003k} + 5.6\times10^{-3}\frac{A}{V}\,\frac{3M\Omega}{3003k\Omega}\right)$$



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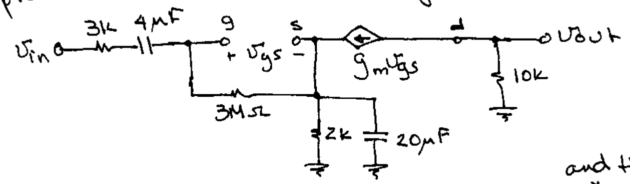

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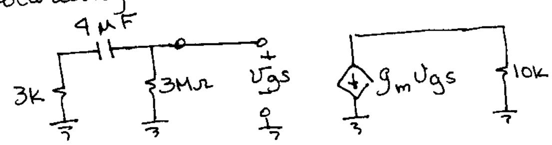

∴ 4µF "sees" 3003kΩ and $\omega_{L_1} = \dfrac{1}{4\mu F\,(3003k)} = \boxed{.08 \text{ rps}}$

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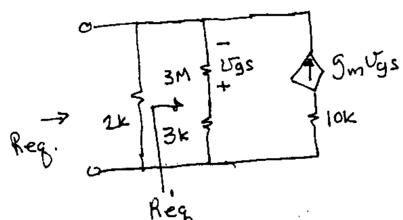
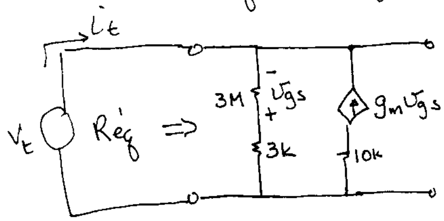


$R_{eq} = 2k \,||\, R_{eq}'$



$$v_{gs} = -\frac{3M}{3003k} V_t$$

$$\therefore\ i_t = \frac{V_t}{3003k} - g_m v_{gs}$$

$$= V_t\left(\frac{1}{3003k} + 5.6\times10^{-3}\frac{A}{V}\,\frac{3M\Omega}{3003k\Omega}\right)$$

$$\therefore\ \frac{V_t}{i_t} = R_{eq}' = 178.7\,\Omega$$

$$\therefore\ R_{eq} = 2k \,||\, 178.7 = 164\,\Omega$$

and $\omega_{L_2} = \dfrac{1}{(20\mu F)(164\,\Omega)} = \boxed{304 \text{ rps} = \text{dominant pole}}$

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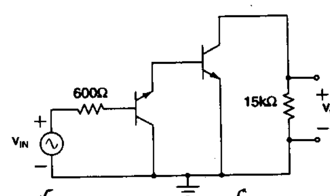
3. The circuit shown below has identical transistors biased at 0.5 mA. Parameters are $r_b = 120\Omega$, $r_\pi = 15k\Omega$, $V_A = 180V$, $C_\pi = 40pF$ and $C_\mu = 4pF$.

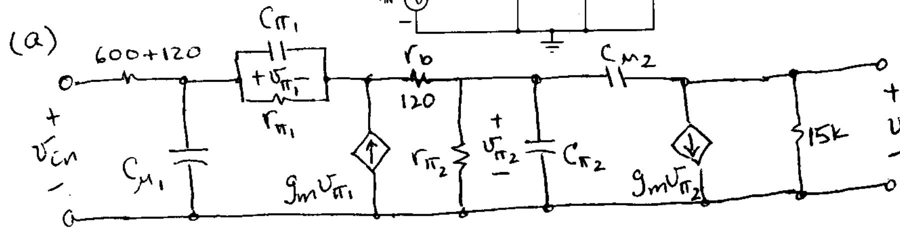
   (a) Draw the high-frequency equivalent circuit. (10 pts)

   (b) Determine the upper half-power frequency for the amplifier. (25 pts)



(neglecting r_o)

(a)



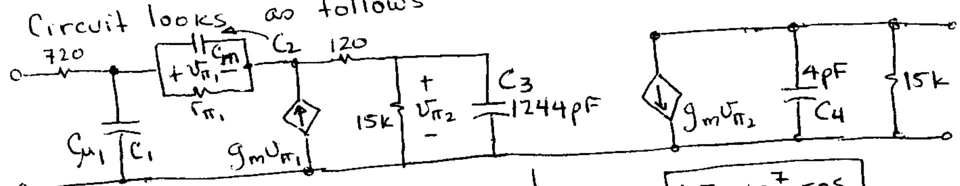
(b) 2^{nd} stage → use Miller's theorem

$$g_m = \frac{I_C}{V_T} = \frac{0.5mA}{25mV} = 0.02\,A/V \quad \Rightarrow \quad A_M = -g_m R_L = -300$$

$$C_{IN} = (1 - A_M) C_{\mu_2} = 301(4pF) = 1204\,pF$$

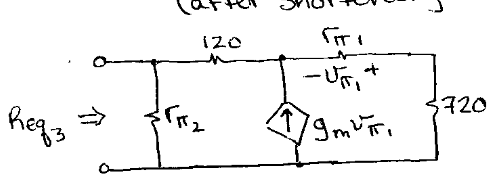
$$C_{out} \cong 4\,pF$$

Circuit looks as follows

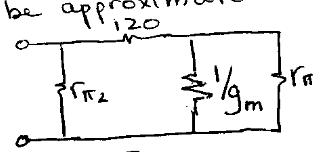


C_4 "sees" 15k $\Rightarrow$ $\omega_{H_4} = \dfrac{1}{4pF\,(15k)} = \boxed{1.7\times10^7 \text{ rps}}$

$C_3 = C_{IN} + C_{\pi_2} = 1244\,pF$ sees the following circuit (after shortening the input source and opening C_1 & C_2)



Since $r_{\pi_1} = 15k >> 720\Omega$ this can be approximated to



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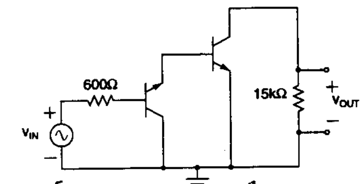
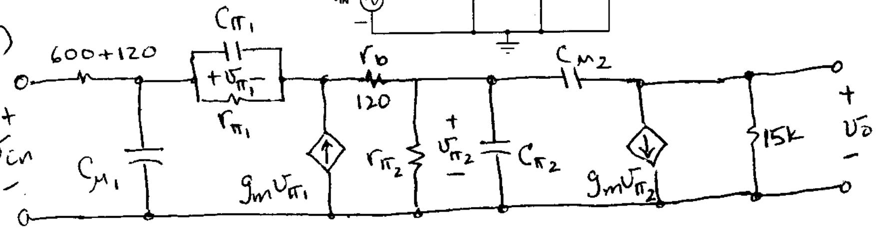


(a)



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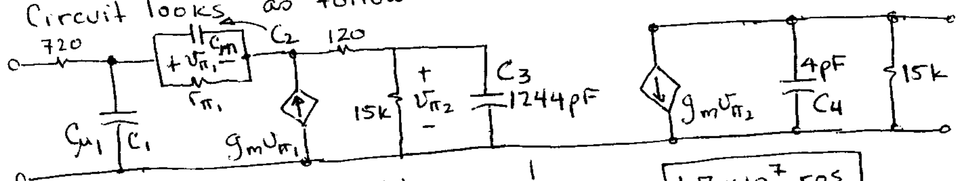

C_4 "sees" 15k $\Rightarrow$ $\omega_{H4} = \dfrac{1}{4pF\,(15k)} = \boxed{1.7 \times 10^7 \text{ rps}}$

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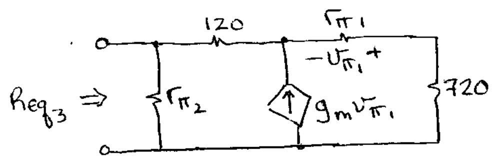

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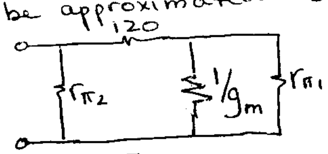


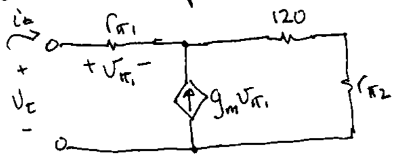
$$\therefore Req_3 = r_{\pi 2} \,\Big|\Big|\, \left[120 + \left(\frac{1}{.02} \,||\, 15k\right)\right]$$

$$= 1.5k \,||\, [170] = 168\Omega$$

$$\therefore \omega_{H3} = \frac{1}{(168)(1244pF)} = \boxed{4.79 \times 10^6 \text{ rps}}$$

Now let's look at the 1st stage

$C_{\mu 1}$ sees 720Ω in parallel with



KVL in the external loop gives

$$v_t = i_t r_{\pi 1} + (i_t + g_m v_{\pi 1})(r_{\pi 2} + 120)$$

$$v_{\pi 1} = i_t r_{\pi 1}$$

$$\therefore \frac{v_t}{i_t} = R'_{eq} = r_{\pi 1} + (1 + g_m r_{\pi 1})(r_{\pi 2} + 120)$$

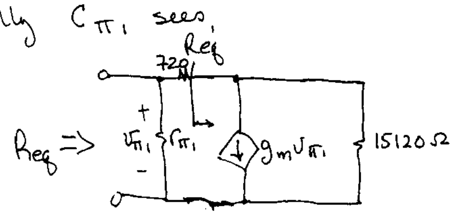
$$= 15k + (1 + .02 \times 15k)(15120\Omega)$$

$$= 4.57 \times 10^6 \ \Omega$$

$\therefore C_{\mu 1}$ sees $720 \| 4.57 \times 10^6 \simeq 720$

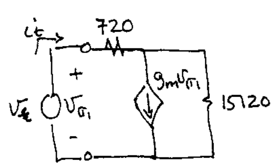
and $\omega_{H\mu 1} = \dfrac{1}{(4pF)(720\Omega)} = \boxed{3.5 \times 10^8 \text{ rps}}$

Finally $C_{\pi 1}$ sees,



$R_{eq} = 15k \| R'_{eq}$

to find R'_{eq}



$$v_{\pi 1} = v_t$$

$$v_t = i_t(720) + (i_t - g_m v_t)15120$$

$$v_t(1 + .02 \times 15120) = i_t(15120 + 72$$

$$R'_{eq} = \frac{v_t}{i_t} = \frac{15840}{303.4} = 52.2\Omega$$

$$R_{eq} = 15k \| 52.2 = 52\Omega$$

$\omega_{H\pi 1} = \dfrac{1}{(40pF)(52\Omega)} = \boxed{4.8 \times 10^{+8} \text{ rps}}$

... 3.5×10^8 rps and 4.8×10^8 rp

∴ the 4 poles are 1.7×10^7 rps, 4.7×10^6 rps, 3.5×10^8 rps and 4.8×10^8 r

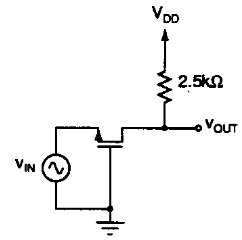
Since there is no dominant pole, we use the effective pole

$$\omega_H = \frac{1}{\frac{1}{4.8\times10^8}+\frac{1}{3.5\times10^8}+\frac{1}{4.7\times10^6}+\frac{1}{1.7\times10^7}} = \boxed{3.6\times10^6}$$

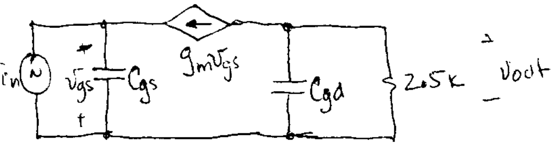
final answer!

Bonus Problem

4. Estimate the mid-band gain and write down an expression for the gain as a function of frequency for the transistor amplifier shown below. Use $g_m = 10mA/V$ and $C_{gs} = C_{gd} = 4pF$. (15 pts)



Replace transistor with model



Since there is no thevenin resistance in the source, Cgs "sees" a short circuit and thus its corresponding pole is at infinity (i.e. does not count). Cgd "sees" 2.5K. Thus

$$\omega_H = \frac{1}{(4pF)(2.5K)} = 10^8 \text{ rps}$$

The mid-band gain can be obtain from the above equivalent circuit, with the caps replaced by open circuits. From the diagram,

$$v_{in} = -v_{gs}$$

$$v_{out} = -g_m v_{gs}(2.5K)$$

$$\therefore \frac{v_{out}}{v_{in}} = A_{mid} = g_m(2.5K) = 25$$

Finally,

$$A_v(s) = 25 \frac{10^8}{s + 10^8}$$