Problem 1

$$\frac{\frac{A}{1+Af} - \frac{1}{f}}{\frac{A}{1+Af}} = \frac{\frac{Af}{(1+Af)f} - \frac{1+Af}{(1+Af)f}}{\frac{A}{1+Af}} = \frac{\cancel{Af} - 1 - \cancel{Af}}{\cancel{(1+Af)}f} \cdot \frac{\cancel{1+Af}}{A}$$

$$= -1/Af \text{ exactly.}$$

if you used $1/f$ here, you needed the $\frac{1}{1+x} \approx 1-x$ approximation but it should be $A/1+Af$.

Problem 2

(a) $$\frac{A}{1+Af} = \frac{1000}{1+1000\cdot 0.1} = 9.901$$

(b) $$\frac{1}{f} = \frac{1}{0.1} = 10$$

(c) $$\frac{A}{1+Af} - \frac{1}{f} = 0.099\ldots$$

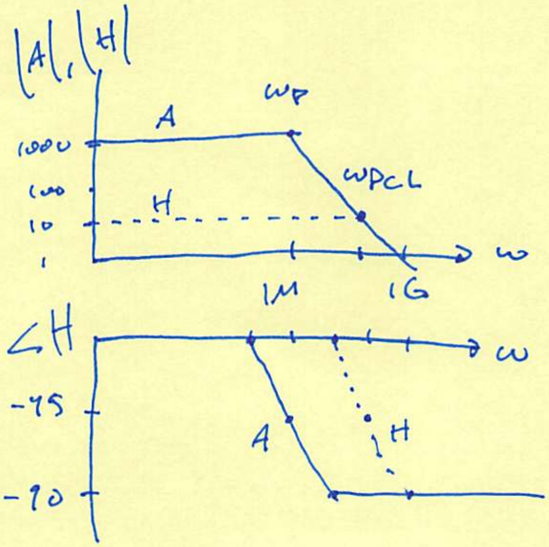
(d) gain error = fractional error x gain

$$= \frac{1}{-Af} \cdot 9.901 = 0.099\ldots$$

same as (c).

Problem 3 (a, b)

$A(s)$: open-loop
$H(s)$: closed-loop



(c) $\omega_u = A_0 \times \omega_p = 1000 \cdot 1M \frac{rad}{s} = 1G \frac{rad}{s}$. (open-loop)

unity-gain freq. doesn't change in feedback: $\omega_{u,CL} = 1G \frac{rad}{s}$

(d) ω_p open-loop $= 1M \frac{rad}{s}$.

ω_p closed-loop $= \omega_{p,OL} \times (1 + Af) \approx 100M \frac{rad}{s}$.

(e) gain-bw product is the same as unity-gain frequency: in both open-loop and closed-loop it's $1G \frac{rad}{s}$.

Problem 4 (a) $\tau = \frac{1}{\omega_{p,OL}} = \frac{1}{1M \frac{rad}{s}} = 1\mu s$

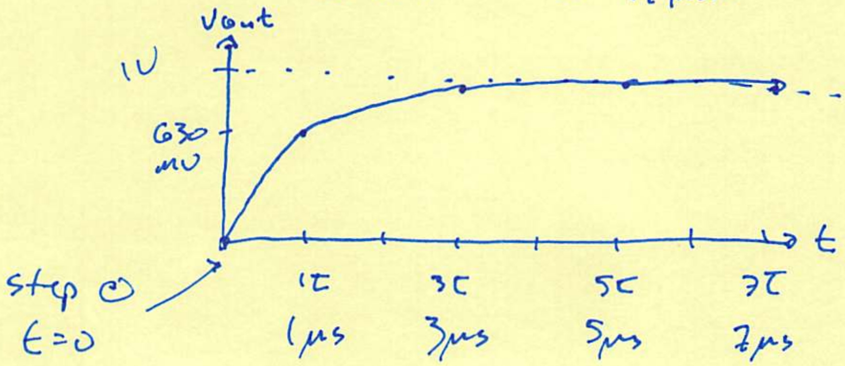
(b) open-loop gain 1000 → $V_{final} = 1mV \times 1000 = 1V$.

after 1τ : $0.63 \cdot 1V = 630mV$

3τ : $0.95 \cdot 1V = 950mV$

5τ : $0.99 \cdot 1V = 990mV$

7τ : $0.999 \cdot 1V = 999mV$



(c) $\tau_{CL} = \frac{1}{\omega_{p\,CL}} = \frac{1}{100M \frac{rad}{s}} = 10ns$

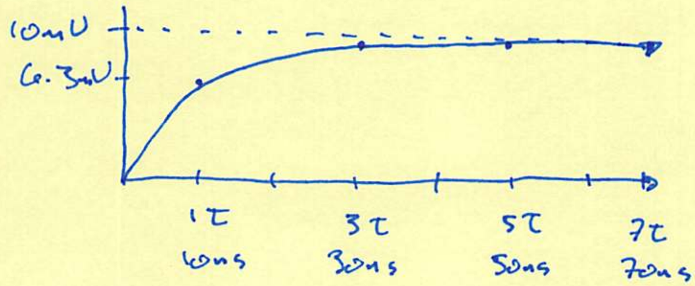
(d) closed-loop gain $\frac{1}{f} = 10$ → $V_{final} = 10mV$.

1τ : $0.63 \cdot 10mV = 6.3mV$

3τ : $0.95 \cdot$ " $= 9.5mV$

5τ : $0.99 \cdot$ " $= 9.9mV$

7τ : $0.999 \cdot$ " $= 9.99mV$



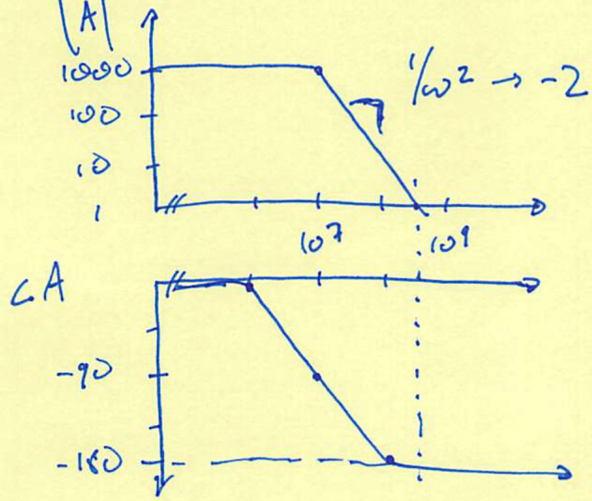
(e) the closed-loop response is 100x shorter in amplitude and 100x faster in time; if plotted with the open-loop response, it would look like a flat line on the t axis.

Problem 5

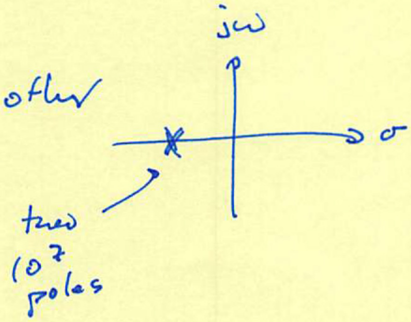
DC gain is $G_{m1} R_{o1} G_{m2} R_{o2} = 1000$

ω_{p1} is $\frac{1}{R_{o1} C_1} = 10^7 \frac{rad}{s}$; $\omega_{p2} = \frac{1}{R_{o2} C_2} = 10^7$

(a)



(b) the poles are on top of each other on the real axis at 10^7 :



(c) if $f = 1$, from (a) we can see the phase margin is approximately Zero.

(d) Technically it's stable because ∠A asymptotically approaches $-180°$, but practically we expect other aspects of the amplifier to push it over the edge of instability. So no, this is not unity-gain stable.

Problem 6 see plots on next page.

(a) $A_{v2,0} = G_{m2} R_{o2} = 10 \frac{V}{V}$; $\omega_{p2} = 10^7 \frac{rad}{s}$ (from problem 5)

(b) Input cap of 2nd stage starts out as C_c w/ Miller multiplication. Eventually the A_{v2} term in $(1-A_{v2})$ dwindles to nothing, leaving only C_c:

$C_c \cdot (1 - A_{v2,0})$ initially → approximate as $1pF \times 10$
(really, it's $1pF \times 9$)

$C_c \cdot 1$ eventually → $1pF$.

Decline follows A_{v2} roll-off after ω_{p2}.

We assume gate cap, etc. of 2nd stage is negligible.

(c) $Z_{in,2}$ is inverse of $C_{in,2}$ from (b); looks capacitive (10pF) with $\frac{1}{\omega}$ slope, then roll-off due to A_{v2} btw 10^7 and 10^8 matches capacitive roll-off and it looks constant, or resistive, then looks capacitive again but along a 1pF line.

Added a line for R_{o1}: flat along $1M\Omega$.

(d) $A_{v1,0} = .1mS \cdot 1M\Omega = 100$. Gain roll-off follows $|Z_{in,2}|$ curve and R_{o1} curve drawn for (c). They're in parallel, so $Z_{out,1} \cong \min(Z_{in,2}, R_{o1})$.

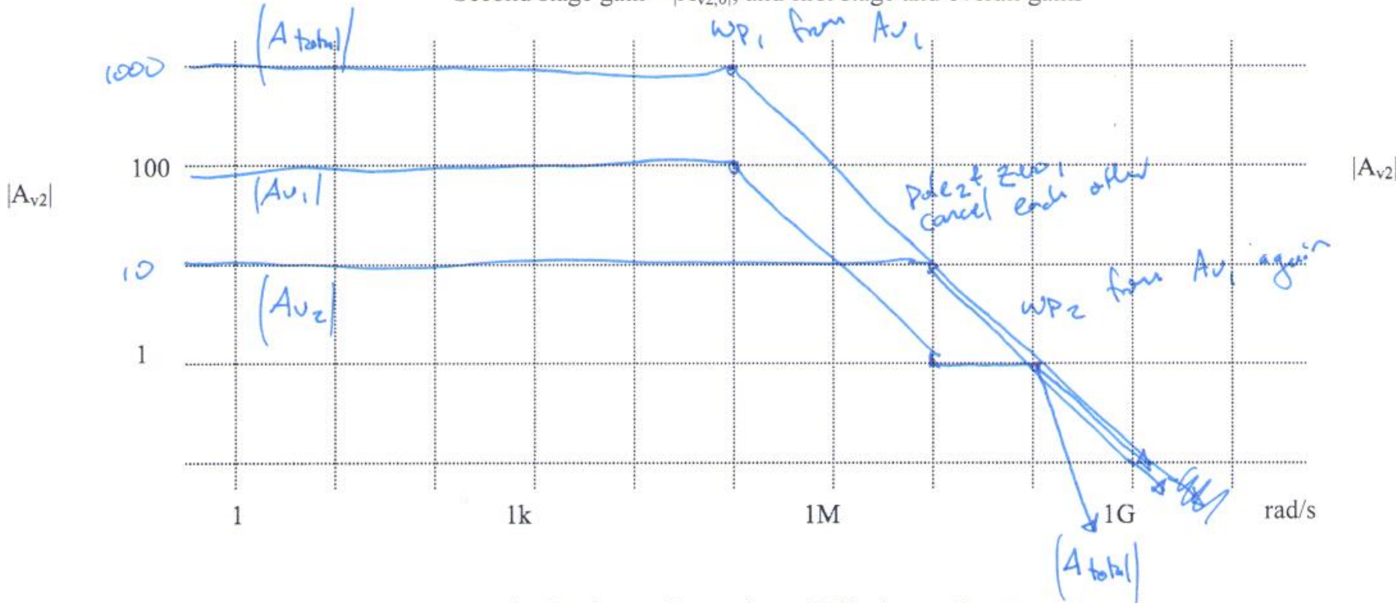
Overall gain is constructed graphically using this and (a). Pole and zero at 10^7 cancel, leaving the appearance of one overall pole at 10^5 rads/s.

(e) real poles + zeros: poles at 10^5, 10^7; zero at 10^7.

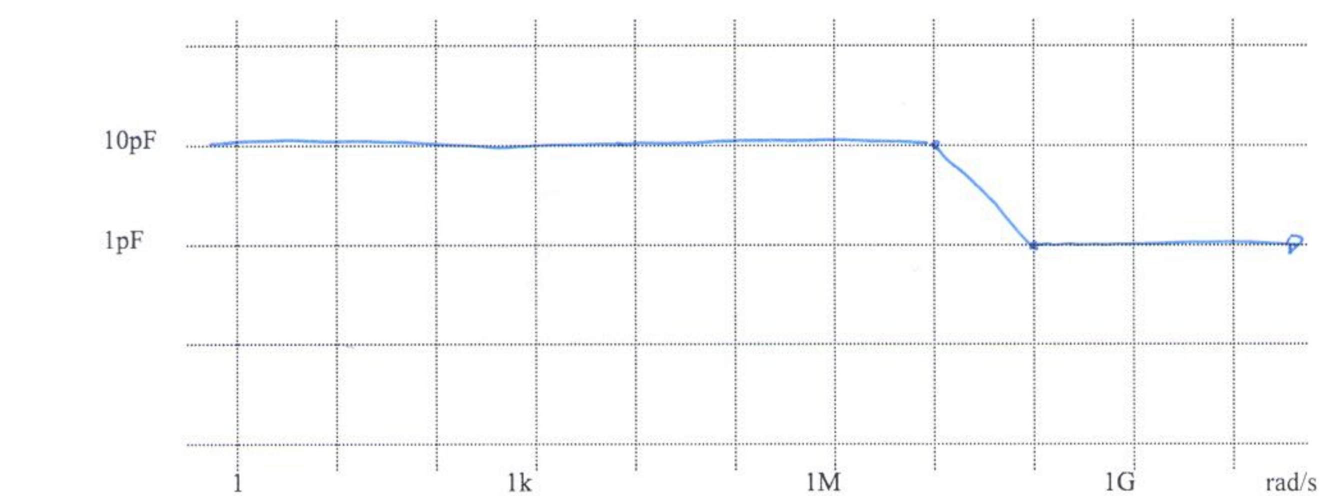
(f) it acts as if it has one pole, so $PM = +90°$.

(g) yes.

Second stage gain – $|A_{v2,0}|$, and first stage and overall gains



magnitude of second stage input (Miller) capacitance



second stage input impedance, and R_{o1}