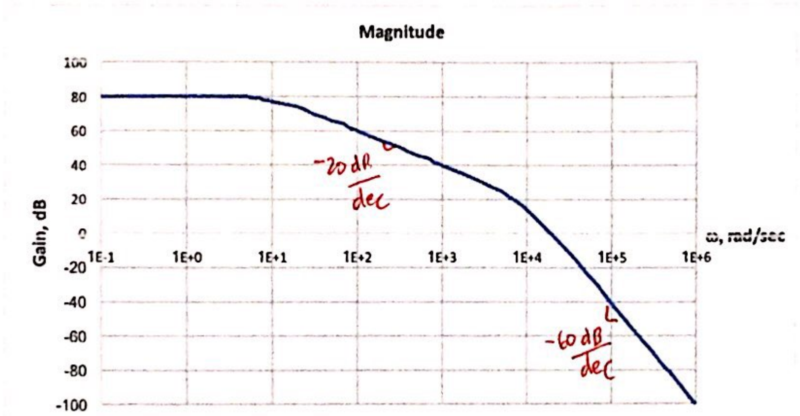
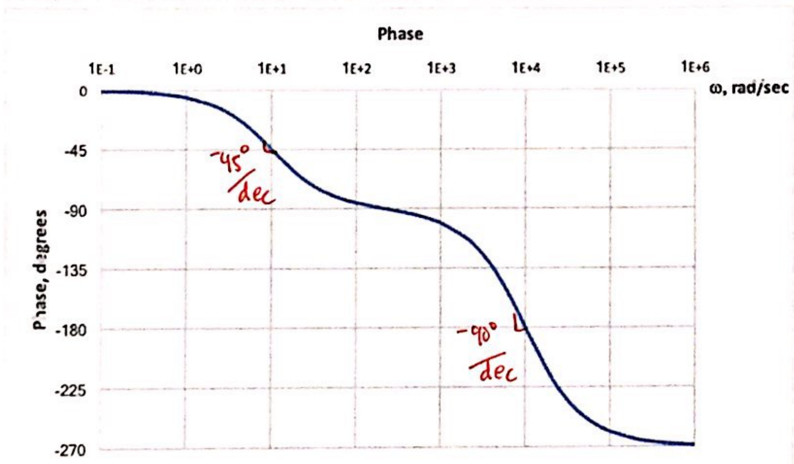
Name: ANSWER KEY	Section:

Part II:

(15 points) The magnitude and phase plots of an operational amplifier are shown below.





1. Determine the transfer function of the operational amplifier's open-loop gain. (*4 points*)

80 dB → 10^4 ; $\omega_{p1} = 10$ rad/sec , $\omega_{p2} = \omega_{p3} = 10^4$ rad/sec

$$a(s) = \frac{10^4}{\left(1+\frac{s}{10}\right)\left(1+\frac{s}{10^4}\right)^2}$$

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2. If the operational amplifier is placed in unity gain feedback, will the system be stable? Why or why not? (*2 points*)

at $f = 1$, $T(s) = a(s)$

from graph, $\angle T(s) = -180^\circ$ at $\omega = 10^4$ rad/sec

since $|T(s)|$ at $\omega = 10^4$ rad/sec is greater than $\emptyset$ dB,

amplifier is NOT stable.

3. Determine the phase margin if this operatonal amplifier is used in a feedback amplifier with a feedback factor of 0.1. (*2 points*)

at $f = 0.1$, $T(s) = \dfrac{10^3}{(1+\frac{s}{10})(1+\frac{s}{10^4})^2}$

at $\omega = 10^4$ rad/sec,

$\angle T(s) = -180^\circ$

$|T(s)| \approx \emptyset$ dB

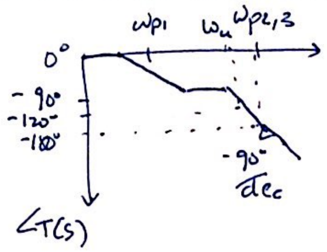
$PM = 0^\circ$

4. What feedback factor should be used for a phase margin of 60 degrees? (*3 points*)

for $PM = 60^\circ$, $\angle T(\omega_u) = -120^\circ$

$$\frac{-90^\circ}{\text{dec}} = \frac{-120-(-180^\circ)}{\log(\omega_u) - \log(10^4)}$$

$\omega_u = 10^{10/3}$ rad/sec



$T_0 \cdot \omega_{p1} = \omega_u$

$T_0 = \dfrac{10^{10/3}}{10} = 10^{7/3}$

$T_0 = a_0 \cdot f \rightarrow f = \dfrac{10^{7/3}}{10^4} = 10^{-5/3}$ or 0.0215

$f = 0.0215$

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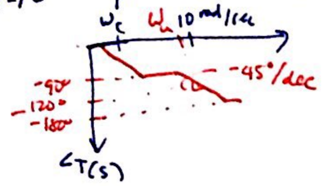
$f=1, \; T_0 = 10^4$

5. Suppose the operational amplifier is placed in unity gain feedback, at what frequency should a dominant pole be added for a phase margin of 60 degrees? (*2 points*)

since a new dominant pole will be added, $\omega_{p2,c} = \omega_{p1} = 10 \text{ rad/sec}$



$$\frac{-45°}{\text{dec}} = \frac{-120° - (-180°)}{\log(\omega_u) - \log(10)}$$

$$\omega_u = 10^{-1/3} \text{ rad/sec}$$

$$T_0 \cdot \omega_c = \omega_u$$

$$\omega_c = \frac{10^{-1/3}}{10^4} = 10^{-13/3} \frac{\text{rad}}{\text{sec}} \text{ or } 4.64 \times 10^{-5} \text{ rad/sec}$$

$\omega_C =$ 46.4 μ rad/sec

6. Suppose the operational amplifier is placed in unity gain feedback, at what frequency should the dominant pole be moved for a phase margin of 60 degrees? (*2 points*)

since original ω_{p1} will be moved, ω_u will be the same as in #4

$$\omega_u = 10^{10/3} \text{ rad/sec}$$

$$T_0 \cdot \omega_c = \omega_u$$

$$\omega_c = \frac{10^{10/3}}{10^4} = 10^{-2/3} \frac{\text{rad}}{\text{sec}} \text{ or } 0.215 \text{ rad/sec}$$

$\omega_C =$ 0.215 rad/sec

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