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Test 1 : CSD

1 a) i) $G(s) = \dfrac{K(s+3)}{(s+4)(s+2+j)(s+2-j)}$

$= \dfrac{K(s+3)}{(s+4)(s^2+4s+5)}$

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1 b) OS = 10 %, $\zeta = 0.59$, $\omega_n = 4.08$

i) dominant poles

Real $= \zeta\omega_n$ $= 2.41$

Img $= \omega_n\sqrt{1-\zeta^2}$ $= 3.29$

Dom. poles $= -2.41 \pm j3.29$

ii) K

$$K = \frac{1}{G(s)} = \frac{|s+4| \cdot |s+2+j| \cdot |s+2-j|}{|s+3|}$$

$$K = 10.69$$

iii) $$G(s) = \frac{K(s+3)}{(s+4)(s^2+4s+5)}$$

$$T(s) = \frac{K(s+3)}{(s+4)(s^2+4s+5)+K(s+3)}$$

~~theta~~

characteristic eqn:

$(s+4)(s^2+4s+5) + K(s+3) = 0$

$s^3 + 8s^2 + (21+K)s + 20+3K = 0$, $K = 10.69$

$s^3 + 8s^2 + 31.69s + 52.07 = 0$

$s = -3.18$

$s = -2.41 \pm 3.25j$

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$$\frac{-3.18}{-2.14} = 1.49 < 5$$

$\therefore$ 2nd order approximation is not valid.

iv) $T_s = \frac{4}{|Real|} = \frac{4}{2.41} = 1.66\,s$

$$T_p = \frac{\pi}{|Img|} = \frac{\pi}{3.29} = 0.95\,s$$

$$K_p = \lim_{s \to 0} k\,G(s)$$

$$= \frac{10.67(3)}{(4)(5)}$$

$$= 1.60$$

$$e_{ss} = \frac{1}{1+K_p} = 0.38$$

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2) $$G(s) = \frac{k(s^2 - 2s + 8)}{(s+3)(s^2+4s+5)}$$

$$S_d = -0.88 \pm j1.72 \quad \text{at} \quad OS = 20\%$$

a) reduce $Ts_n = \frac{3}{5} Ts$, maintain OS.

$$Ts = \frac{4}{|Real|} = \frac{4}{0.88} = 4.55\ s$$

$$Ts_n = \frac{3}{5}(4.55) = 2.73\ s \rightarrow new$$

$$Real_{new} = \frac{4}{2.73} = 1.47$$

~~$\zeta\omega_n =$~~

$$\zeta = \frac{-\ln(OS\%)}{\sqrt{\pi^2 + \ln^2 OS\%}}$$

$$= 0.46$$

$$\zeta\omega_n = 1.47$$

$$\omega_n = 3.20$$

$$Img_{new} = \omega_n \sqrt{1 - \zeta^2}$$

$$= 3.2\sqrt{1 - 0.46^2}$$

$$= 2.84$$

CL poles : $-1.47 \pm j\,2.84$

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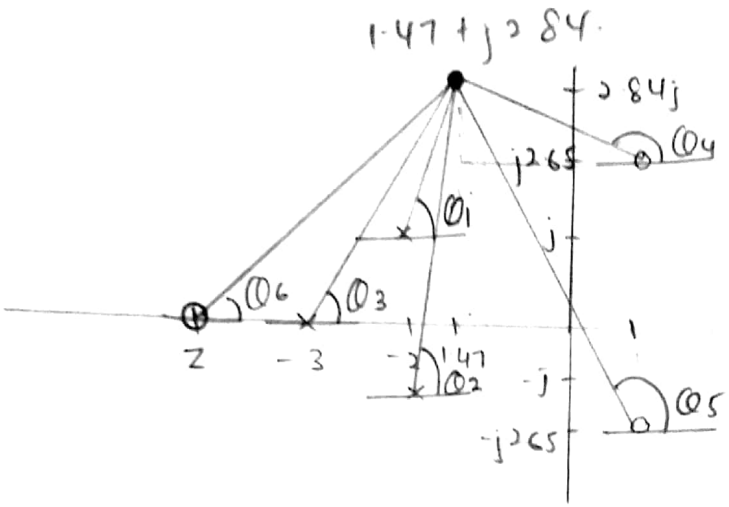

pole = $-3, -2 \pm i$

zeros = $1 \pm j\sqrt{7}$

$= 1 \pm j2.65$

$$\theta_1 = \tan^{-1}\left(\frac{1.84}{0.53}\right) = 73.93^\circ$$

$$\theta_2 = \tan^{-1}\left(\frac{3.84}{0.53}\right) = 82.14^\circ$$

$$\theta_3 = \tan^{-1}\left(\frac{2.84}{1.53}\right) = 61.69^\circ$$

$$\alpha_4 = \tan^{-1}\left(\frac{0.19}{2.47}\right) = 4.40^\circ$$

$$\theta_4 = 180^\circ - \alpha_4 = 175.6^\circ$$

$$\alpha_5 = \tan^{-1}\left(\frac{5.49}{2.47}\right) = 65.78^\circ$$

$$\theta_5 = 180^\circ - \alpha_5 = 114.22^\circ$$

$$73.93 + 82.14 + 61.69 - 175.6 - 114.22 - \theta_6 = 180^\circ$$

$$\theta_6 = -256.4$$

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3 a) $G(s) = \frac{12}{s(s+6)} = \frac{12}{s^2+6s}$

i) in dB

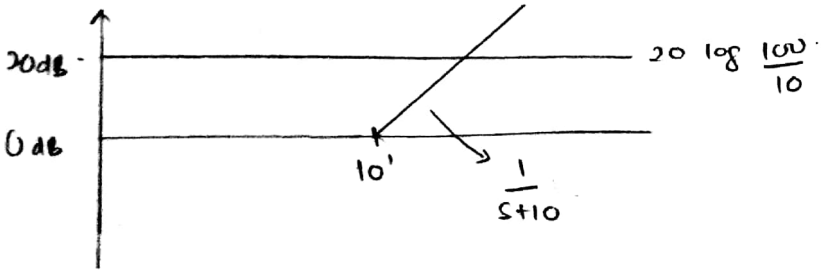
$20 \log |G(j\omega)| = 20 \log 12 - 20 \log |j\omega| - 20 \log |(j\omega+6)|$

ii) magnitude if $\omega = 20$

$$|G(j\omega)| = \frac{12}{\sqrt{\omega^2} \cdot (\sqrt{\omega^2+36})}$$

$$= 0.03$$

b) $G(s) = \frac{100}{(s+10)} = \frac{100}{10\left(\frac{s}{10}+1\right)}$



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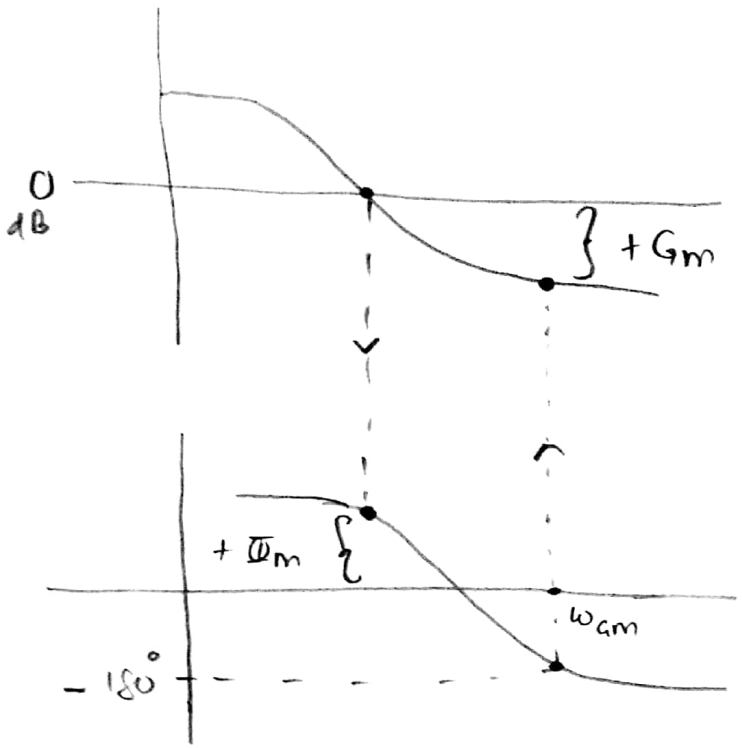
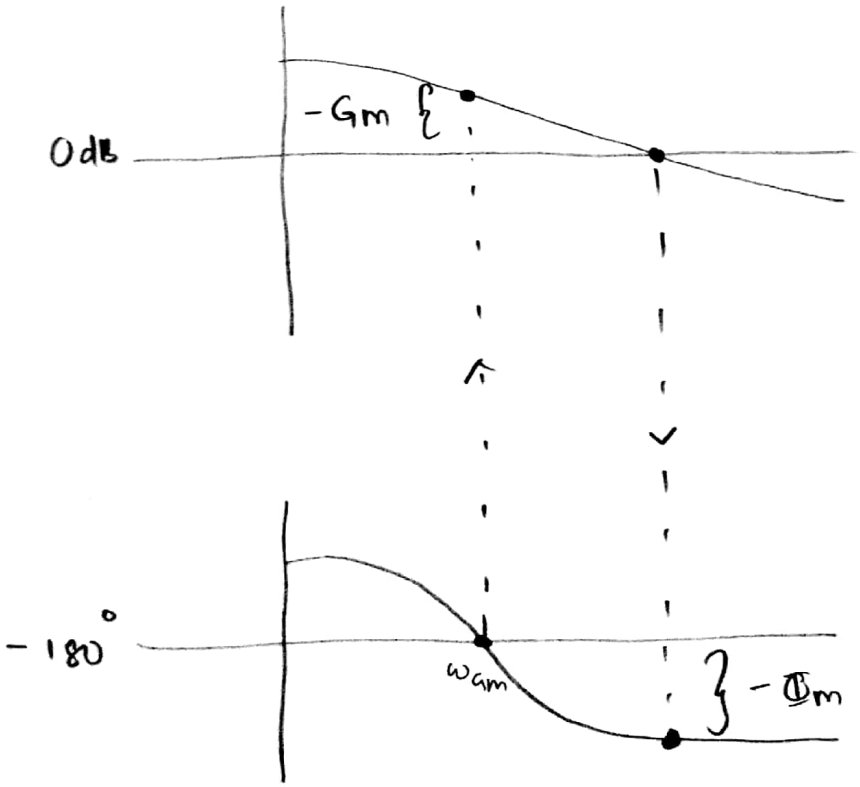
c)



since Gm and Φm is positive, system is stable.



since Gm and Φm is negative, system is unstable.

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