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Ref: Date:

Q1

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

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

ii asymtote point

$\sigma_a = \dfrac{-4-2-2+3}{3-1}$

$= -5/2$

$\theta_a = \dfrac{(2k+1)\pi}{3-1}$

$= \dfrac{(2k+1)\pi}{2}$

$k = 0, 1, 2.$

$\theta_a = \frac{\pi}{2} = 90°$

$\theta_a = \frac{3\pi}{2} = 270°$

$\theta_a = \frac{5\pi}{2} = 450°$

angle of departure

$\theta = \tan^{-1}(1) - [\tan^{-1}(\frac{1}{2} + 90] + 180°$

$= 108.43°$

(b) $OS = 10\%$ $\zeta = 0.59$ $W_n = 4.08$ rad/s

(i)

$|\text{real part}| = \zeta W_n$
$= 0.59 \times 4.08$
$= 2.4072$

$|\text{imaginary part}| = W_n \sqrt{1-\zeta^2}$
$= 4.08 \sqrt{1-(0.59)^2}$
$= 3.294$

$\therefore$ dominant pole $= -2.4072 \pm 3.294j$

(ii)

$$K = \frac{1}{|G(s)|}$$

$$= \frac{|s+4||s-2+j||s-2-j|}{|s+3|}$$ substitue $s = -2.4072 \pm 3.294j$

$$= 8.1279$$

(iii)

$$\text{ratio} = \frac{|-4|}{|-2.4072|} = 1.66 < 5$$

$\therefore$ the second order approximation is not valid.

(iv) $$T_s = \frac{4}{|\text{real}|} = \frac{4}{2.4072} = 1.66\,s$$

$$T_p = \frac{\pi}{|\text{imag}|} = \frac{\pi}{3.294} = 0.9537\,s$$

$$K_p = \lim_{s \to 0} G(s)$$
$$= \lim_{s \to 0} \frac{K(s+3)}{(s+4)(s-2+j)(s-2-j)}$$
$$= \frac{8.1279(3)}{(4)(-2+j)(-2-j)}$$
$$= 1.2192$$

$$e_{ss} = \frac{1}{1+K_p} = \frac{1}{1+1.2192}$$
$$= 0.4506 \#$$

Q2

(a) $T_{s_{old}} = \frac{4}{|real|} = \frac{4}{0.88} = 4.55\,s$

$\%OS = 20\%$ #

$\zeta = \frac{-\ln\left(\frac{20}{100}\right)}{\sqrt{\pi^2+\ln^2\left(\frac{20}{100}\right)}} = 0.4559$

$T_{s_{new}} = \frac{4}{|real_{new}|} = 4.55 \times \frac{3}{5}$

$|real_{new}| = 1.4652$

$\tan^{-1}\left(\frac{imag_{new}}{real_{new}}\right) = \cos^{-1}(0.4559)$

$\tan^{-1}\left(\frac{imag}{1.4652}\right) = 62.88^\circ$

$img_{new} = 2.8604$

dominant poles $= -1.4652 \pm 2.8604j$

$G_{PD} = (s+z)$

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

$\cancel{\angle s+z = [\angle}$

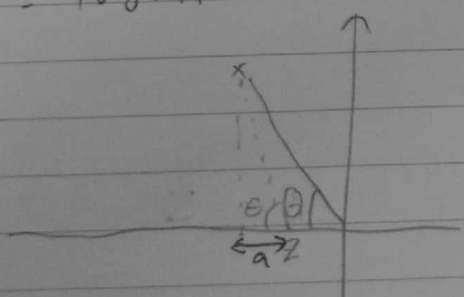
$\angle s+z + \angle s^2-2s+8 - [\angle s+3 + \angle s^2+4s+5] = 180^\circ$

sub $s = -1.4652 + 2.8604j$

$\angle s+z + (-70.86) - [61.78^\circ + 156.07] = 180^\circ$

$\angle s+z = 468.71$

$= 108.71^\circ$



$\tan(180-108.71) = \frac{2.8604}{a}$

$a = 0.9687$

≈ 0.97

$z = -(1.4652 - 0.97)$

$= -0.4952$

≈ -0.5

PD controller

$\therefore\ G_{PD} = \cancel{(z+0.5)}$

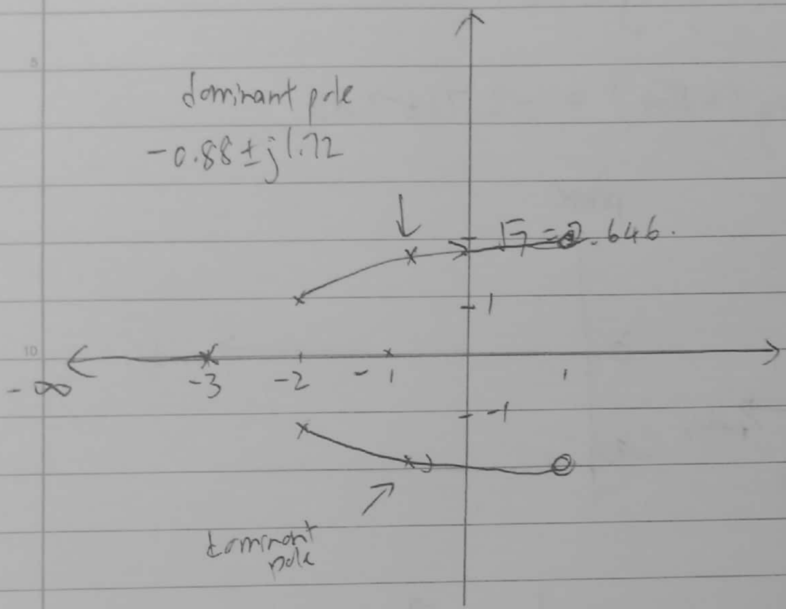
$G_{PD} = (s+0.5)$

Q2 (b)

uncompensated

zeros = $1 \pm \sqrt{7}\, i$

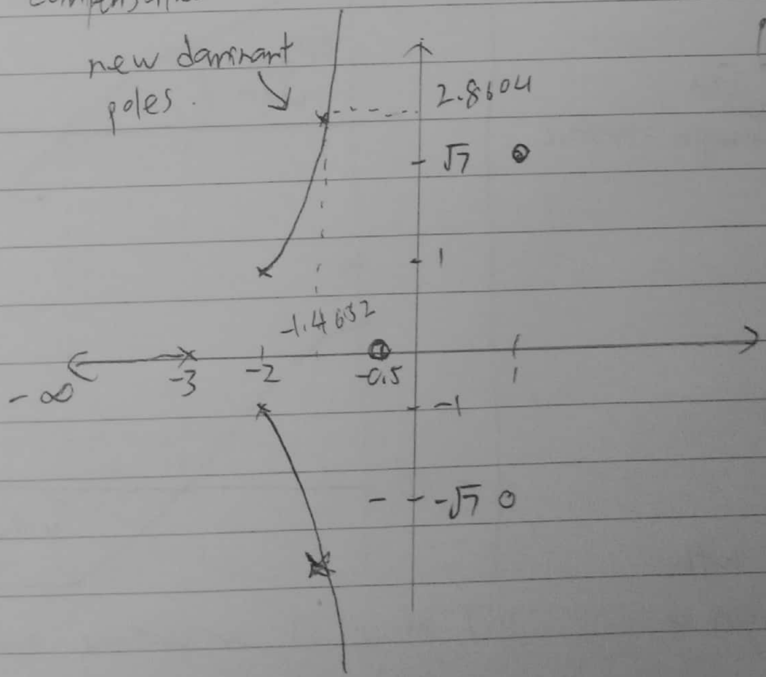
poles = -3, $-2+i$, $-2-i$



compensated

zero = $1 \pm \sqrt{7} i$, -0.5

poles = -3, $-2+i$, $-2-i$



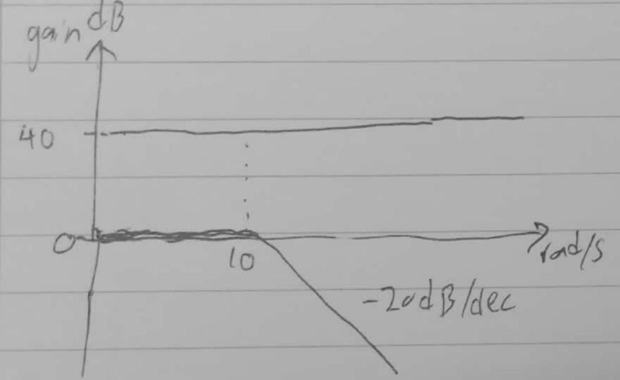
Q3

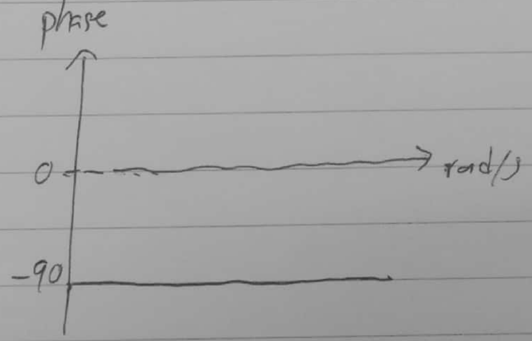
(a) (i) $20\log 12 - 20\log|jw| - 20\log|jw+6|$

(ii) $20\log 12 - 20\log|j20| - 20\log|j20+6|$

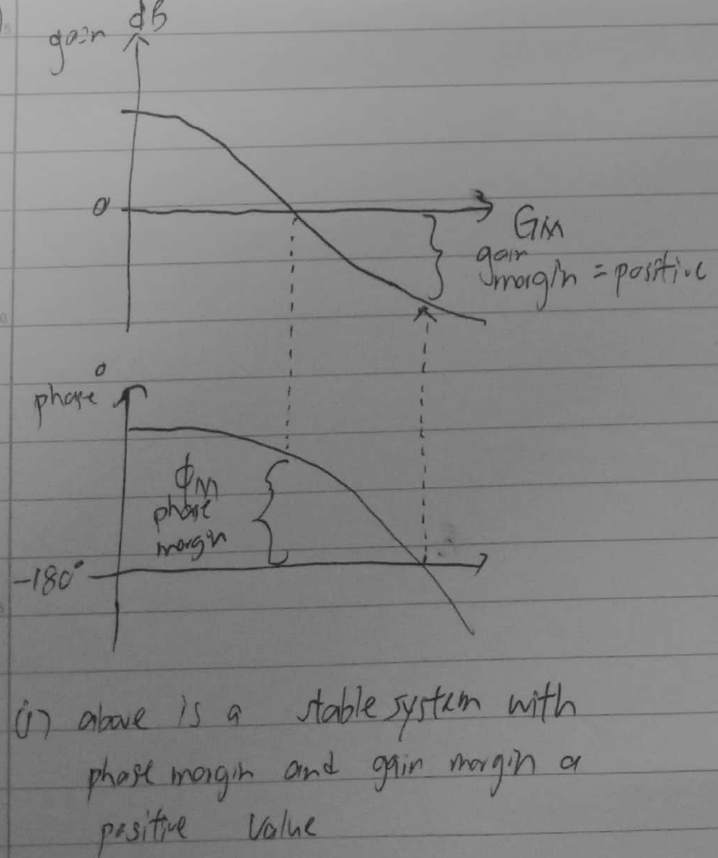
$20\log 12 - 26.02\,dB - 20\log(2\sqrt{109}) = -2.7167\,dB$

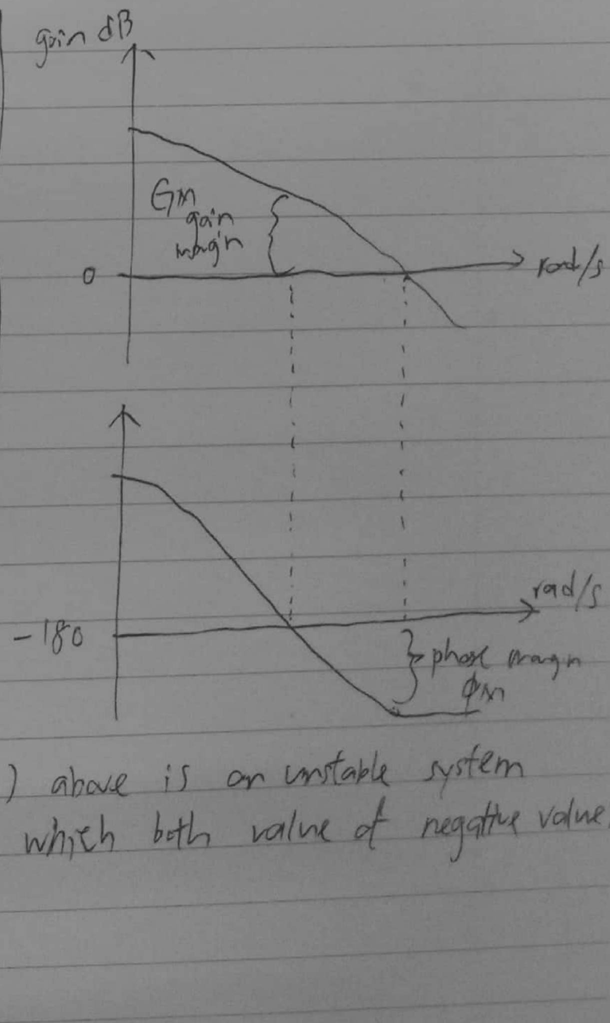
(b)





(c)





(i) above is a stable system with phase margin and gain margin a positive value

(ii) above is an unstable system which both value of negative values