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QUESTION 1

$-2 \pm j$

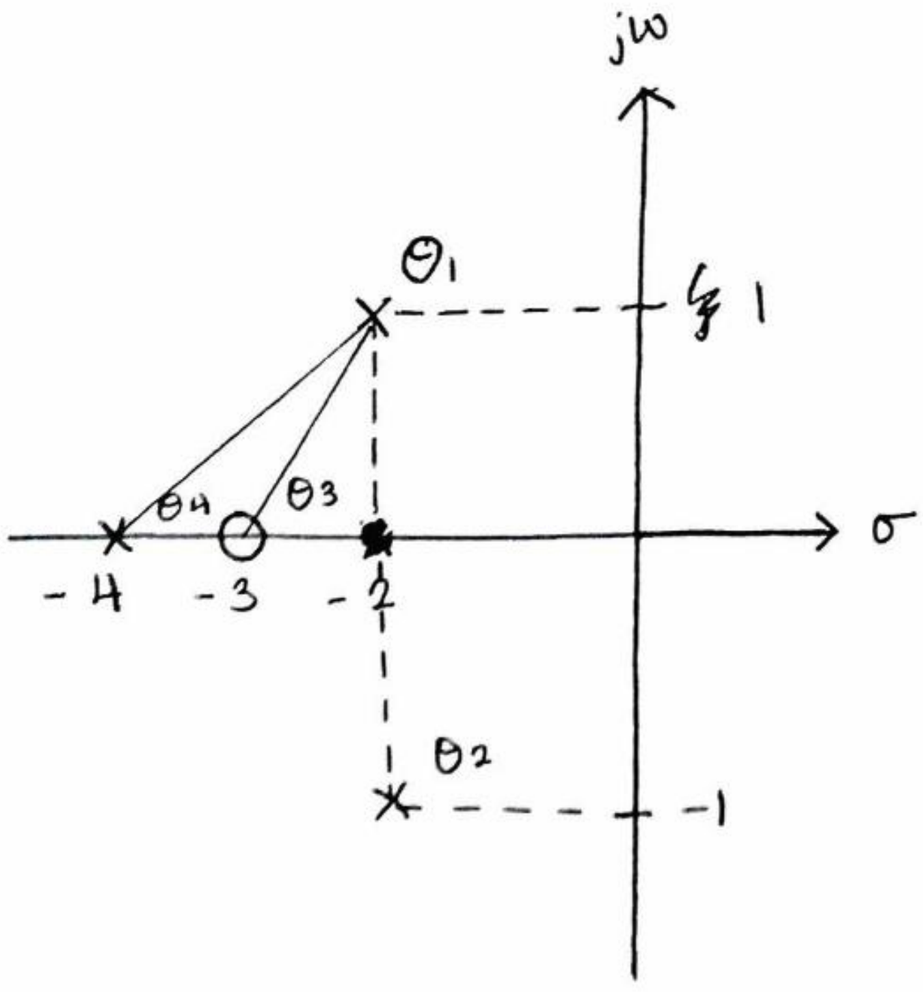
(a)(i) $$G(s) = \frac{(s+3)}{(s+4)(s+2-j)(s+2+j)}$$

(ii) $$\sigma_a = \frac{[4 + (-2+j) + (-2-j)] - (-3)}{3-1}$$

$$= \frac{3}{2}$$

$$\theta_a = \frac{(2k+1)\pi}{3-1} = \frac{\pi}{2}, \frac{3}{2}\pi, \frac{5}{2}\pi$$

(iii)



Angle of departure, θ_1

$\theta_2 = 90°$

From RL,

$\theta_3 = \tan^{-1}\left(\frac{1}{1}\right) = 45°$

$\theta_4 = \tan^{-1}\left(\frac{1}{2}\right) = 26.6°$

$\theta_d = \theta_1 = 45° - (90° + 26.6°) + 180°$

$= 108.4°$

(b) $\%.05 = 10\%$

$\zeta = 0.59$

$\omega_n = 4.08$

(i) $S = -(0.59)(4.08) + 4.08\sqrt{1-(0.59)^2}$

$S = -2.4 + j3.3$

(ii) $K = \dfrac{1}{|G(s)|} = \left.\dfrac{|s+4||s+2-j||s+2+j|}{|s+3|}\right|_{s \to -2.4+j3.3}$

$= 8.4$

(iii) Char eqn $\Rightarrow (s+4)(s+2-j)(s+2+j) + 8.4(s+3)$

$\Rightarrow s^3 + 8s^2 + 29.4s + 45.2$

Poles $\Rightarrow -3.23, -2.38 \pm j2.88$

$= \dfrac{3.23}{2.38} = 1.36 \angle 5$

$\therefore$ not valid second order approximation

(iv) $T_s = \frac{4}{|Real|} = \frac{4}{2.4} = 1.67\ s$

$$T_p = \frac{\pi}{4.08\sqrt{1-(0.59)^2}} = 0.95\ s$$

$G(s) \Rightarrow$ type 0

$$K_p = \lim_{s \to 0} K G(s) = \frac{8.4(3)}{4(2-j)(2+j)} = 1.26$$

$$e_{ss} = \frac{1}{1+1.26} = 0.44$$

QUESTION 2

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

OL zeros: $1 \pm j\,2.65$

OL poles: $-3, -1 \pm j\,1.22$

$s_d = -0.88 \pm j\,1.72$

$\%OS = 20\%$

(a) Char eqn

$$\zeta = \frac{-\ln(20/100)}{\sqrt{\pi^2 + \ln(20/100)^2}} = 0.456$$

$$T_s = \frac{4}{0.88} = 4.55\ s$$

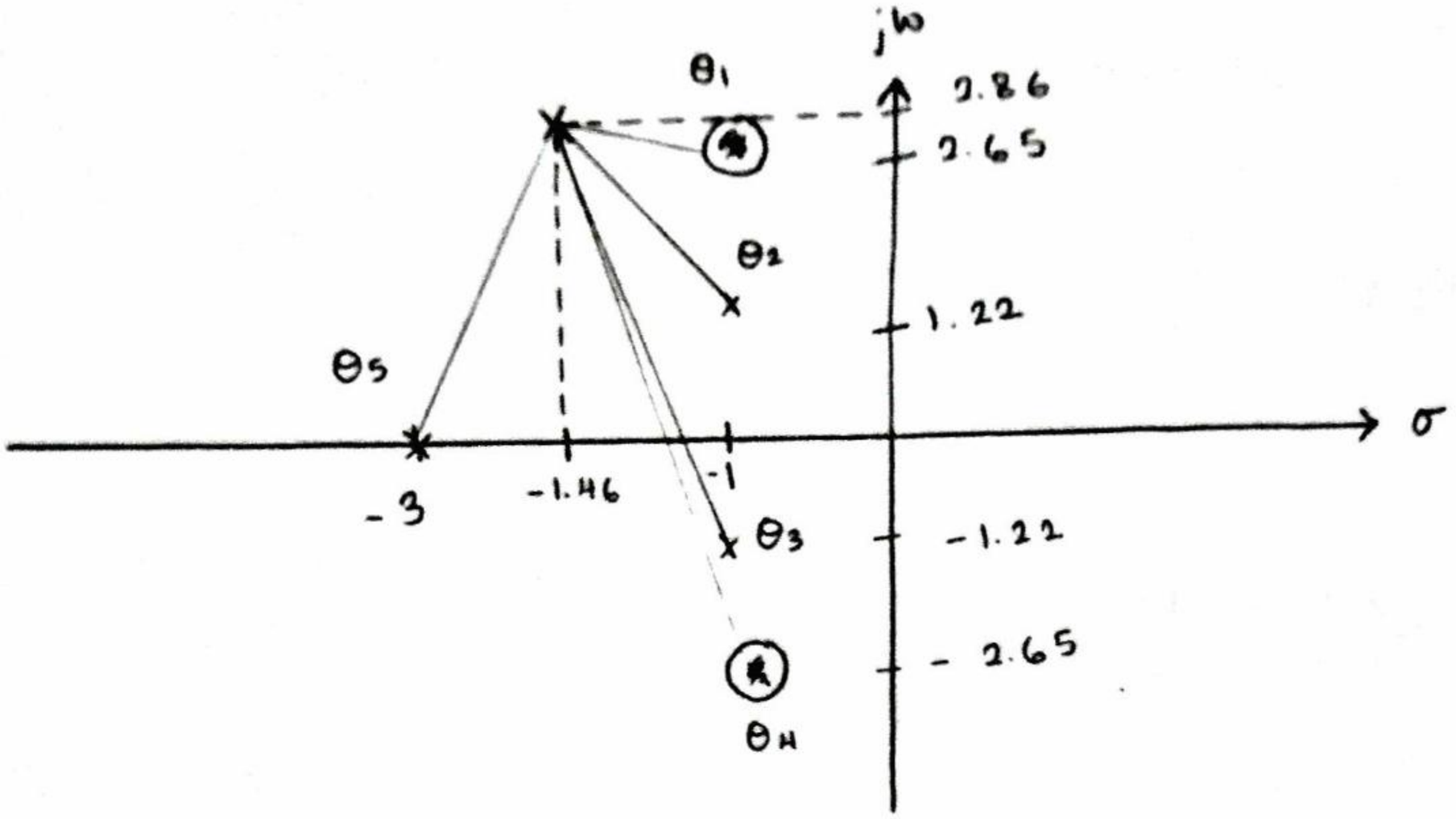
$$T_{s\,new} = \frac{3}{5}(4.55) = 2.73\ s$$

$$2.73 = \frac{4}{(0.456)\omega_n}$$

$$\omega_n = \frac{4}{(0.456)(2.73)} = 3.21$$

$$s = -(3.21)(0.456) \pm j\,(3.21)\sqrt{1-(0.456)^2}$$

$$= -1.46 \pm j\,2.86$$



θ1

QUESTION 3

(a) (i) $G(s) = \dfrac{12}{s(s+6)}$

$$G(s) = \frac{12}{6} \quad \frac{1}{s(s/6+1)}$$

$20 \log 12/6 = 6.02$ dB

$= 20 \log 2 - (20 \log s + 20 \log (\frac{s}{6} + 1)$

(ii) 6.02 dB $- 38.78$ dB

$= -32.74$ dB

(b) $G(s) = \dfrac{100}{s + 10}$

Constant

$|G(jw)| = 20 \log 100 = 40$

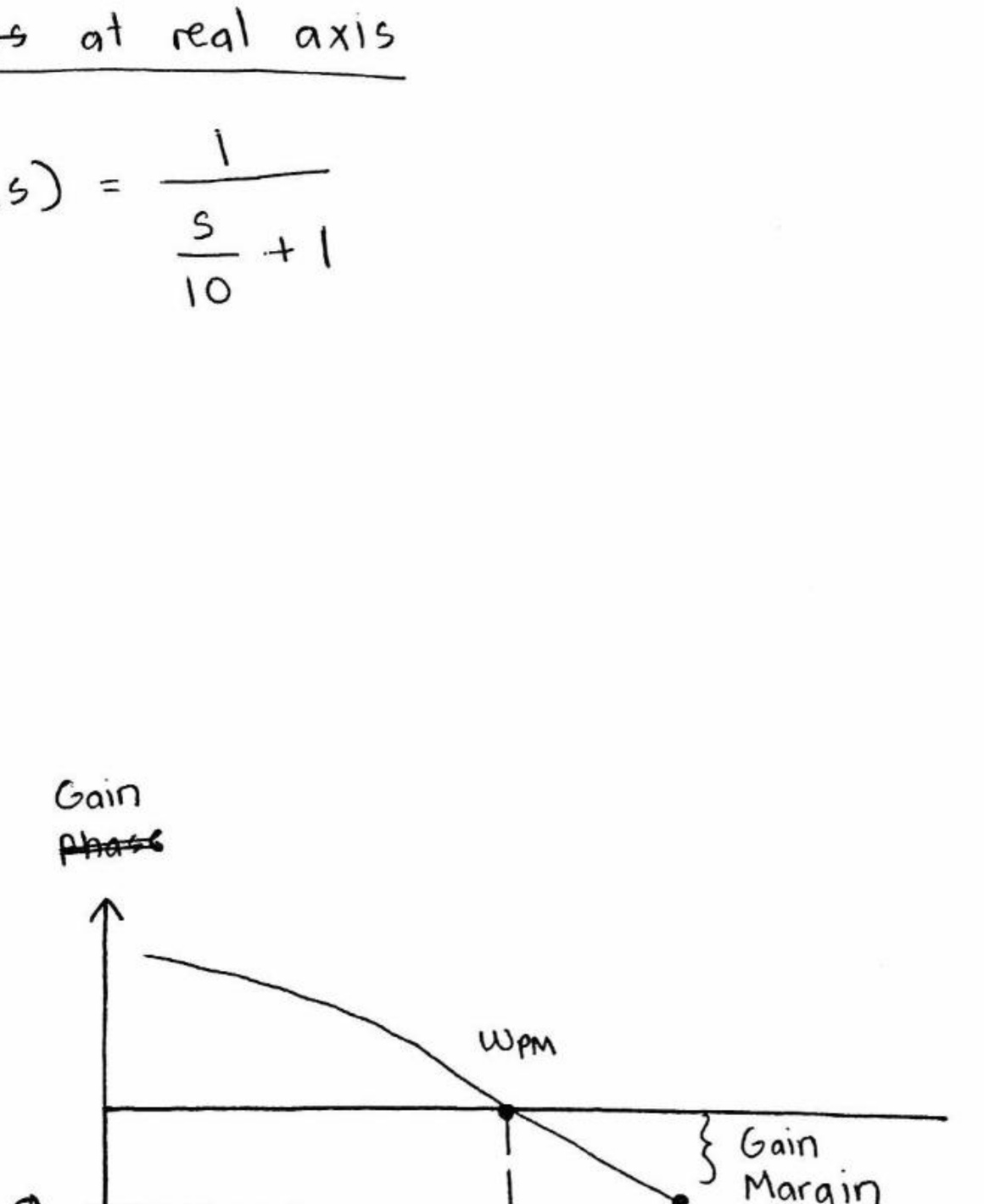
$\angle G(jw) = 0°$

Poles

~~Zeros~~ at real axis

$G(s) = \dfrac{1}{\frac{s}{10} + 1}$

(c) (i)



$GM = 0 - (-a)$

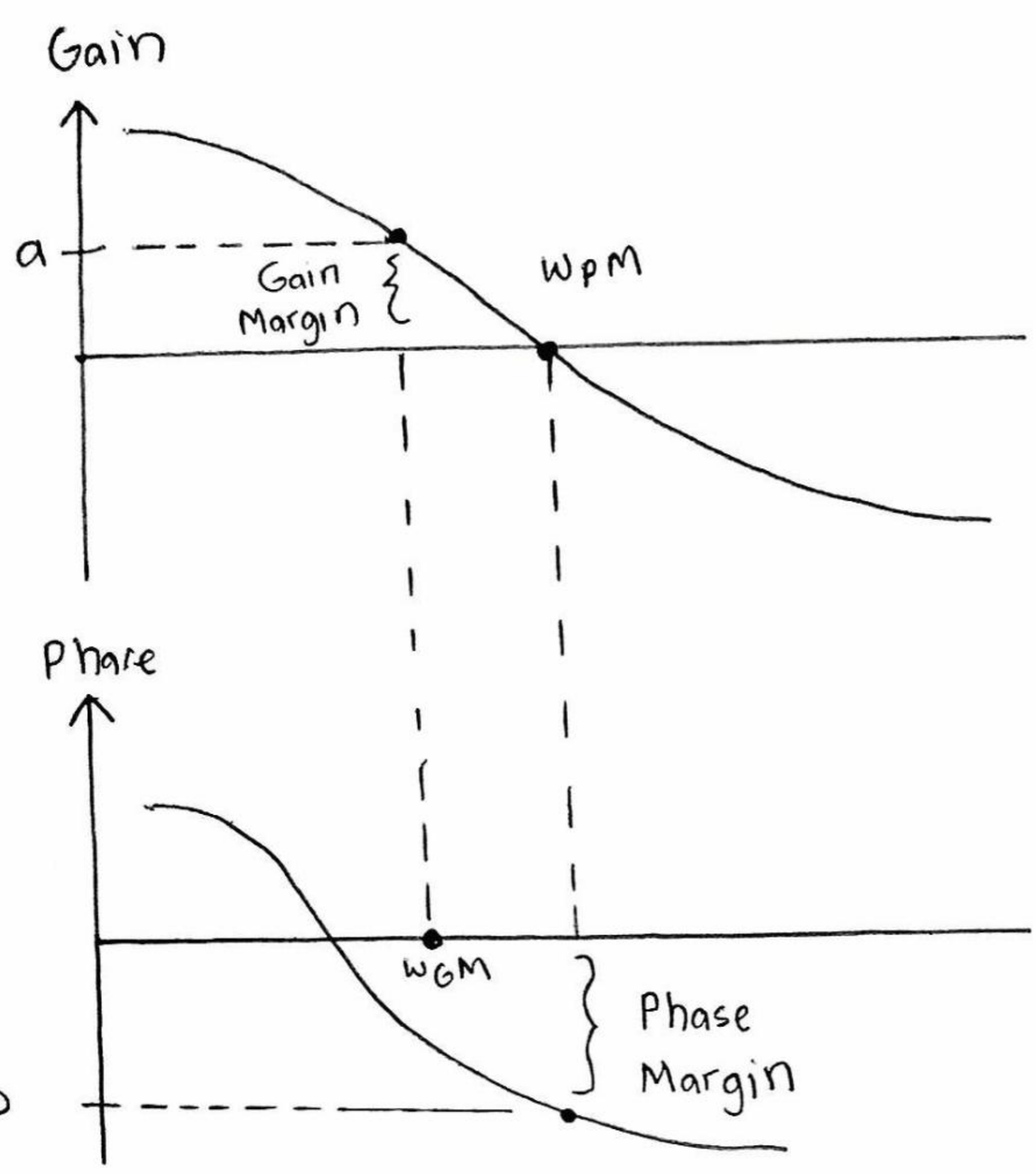
$= +ve$

$PM = b - (-180)$

$= +ve$

∴ The system is stable because of positive GM & PM

i)



$$GM = 0 - a$$
$$= -ve$$

$$PM = -b - (-180)$$
$$= -ve$$

∴ The system is unstable because of -ve GM & PM