① - $K=1$

a) $K_v = ?$ $\quad K_v \approx j\omega G_1(j\omega)$, ω pequeno : na tabela $\underline{\omega = 0.01}$

$\Rightarrow 20 \log K_v = 20 \log(0.01) + 49.52 \Rightarrow \log K_v = \frac{49.52 - 40}{20} \Rightarrow K_v = 10^{9.52/20} \Rightarrow \boxed{K_v = 1.499}$

b) $\alpha = 0.25$

$\operatorname{sen} \phi_m = \frac{1-\alpha}{1+\alpha} \Rightarrow \operatorname{sen} \phi_m = \frac{0.75}{1.25} = 0.6 \Rightarrow \phi_m = \operatorname{asin}(0.6) \Rightarrow \boxed{\phi_m = 0.6435 \text{ ou } 36.869^\circ}$

MF original: $180 - 148.16 \approx 31.84^\circ$

MF compensado: $31.84 + 36.869 = \boxed{68.709^\circ}$

c) $\alpha = 0.25 \Rightarrow 20 \log \frac{1}{\sqrt{\alpha}} : \underline{6.02 \text{ dB}}$

Procurando por -6.02 dB na tabela tem-se $\omega = 1.64$ (-5.29 dB)

$\omega_c = \frac{1}{T\sqrt{\alpha}} \Rightarrow T = \frac{1}{1.64\sqrt{0.25}} = \boxed{1.219}$ $\quad$ zero $= \frac{1}{T} : 0.82$ $\quad$ $K_c\alpha = 1 \Rightarrow K_c = 4$

pólo : $\frac{1}{\alpha T} : 3.28$

$$\boxed{C(s): \frac{4(s+0.82)}{(s+3.28)} = \frac{(1.219s+1)}{(0.304s+1)}}$$

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② - MF $= 41^\circ$ $\quad K = K_c\beta = 1$

MF original : 31.84°

MF desejada : $41^\circ \Rightarrow \angle G_1(j\omega) : -180 + 41 = -139^\circ$

Na tabela : -131.22° (foi dada uma folga) $\boxed{\omega = 0.75 \text{ rad/s}}$ $\cdot$ atenuação 4.85 dB

b)

$-20 \log \beta = -4.85 \Rightarrow \beta = 10^{4.85/20} : \boxed{1.747}$

c) Uma década abaixo : $0.075 = \omega_z$

$T = \frac{1}{\omega_z} \Rightarrow T : 13.333$ $\quad$ zero : 0.075

$K_c\beta = 1 \Rightarrow K_c = \frac{1}{1.747} = 0.572$ $\quad$ pólo $\frac{1}{\beta T}$: ~~0.0429~~ : ~~0.055~~ : 0.0429

$$C(s): \frac{0.572(s+0.075)}{(s+0.0429} = \frac{(13.33s+1}{(23.30s+}$$

---

③ - Estável se MF >0 ou $\angle P(j\omega) > -180^\circ$

$|P(j\omega)| = 1 \Rightarrow \frac{5}{\sqrt{\omega^2+1}\sqrt{\omega^2+1}} = 1 \Rightarrow \omega^2+1 = 5 \Rightarrow \omega = \pm\sqrt{4} \Rightarrow \boxed{\omega = 2}$

$\angle P(j2) > -\pi \Rightarrow -2\tau 2 - 2\operatorname{atan}(2) > -\pi \Rightarrow \tau < \frac{\pi - 2\operatorname{atan}(2)}{4} \Rightarrow \boxed{\tau < 0.231}$

④ $C(s)=K \quad P(s)=\dfrac{3}{s(s+1)(s+9)}$: $p_1=0,\ p_2=-1 \quad p_3=-9$

$n=3,\ m=0,\ n-m=3$, Assint: $60, -60, 180$, $\sigma_a=\dfrac{-9-1}{3}=-10/3=-3.333$

$D(s)=s^3+10s^2+9s$

$D'(s)=3s^2+20s+9$

$N(s)=3$

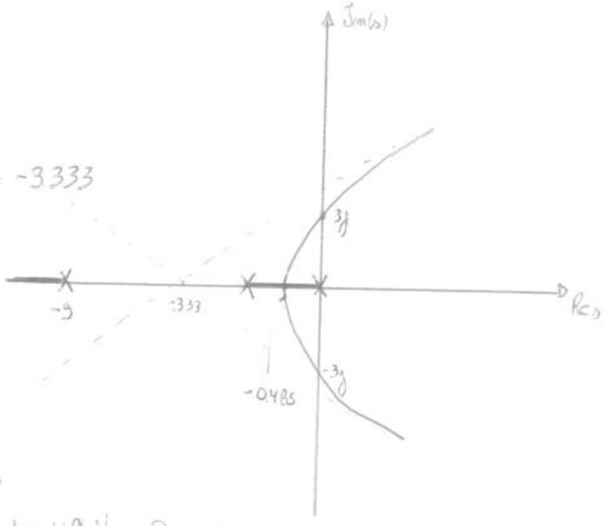
$N'(s)=0$

$D'(s)N(s)-D(s)N'(s)=0 \Rightarrow (3s^2+20s+9)\,3=0 \Rightarrow \boxed{s_1=-0.485} \Rightarrow$

$s_2=-6.18$

$1+KP(s)\big|_{s=-0.485}=0 \Rightarrow$

$K=-\dfrac{1}{P(-0.485)}=\boxed{0.708}$



$D(j\omega)+KN(j\omega)=0+0j \Rightarrow -j\omega^3-10\omega^2+9\omega j+3K=0 \Rightarrow$

$3K=10\omega^2 \Rightarrow \boxed{K=30}$

$9\omega=\omega^3 \Rightarrow \omega^2=9 \Rightarrow \omega=\pm3 \Rightarrow \boxed{\omega=3}$

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⑤ a) $G(s)=\dfrac{-1}{1+\dfrac{(-10)}{s(s+4)}}=\dfrac{-1}{\underbrace{s^2+4s-10}}$

raiz positiva $\Rightarrow$ Sistema Instável!

b) $G(s)=\dfrac{2}{\underbrace{s^2+6s+10}}$

raízes com parte real negativa $\Rightarrow$ sistema estável.

$K_p=\lim_{s\to0} C(s)P(s)=\dfrac{2}{8}=1/4$ $\qquad e_d=\dfrac{1}{1+K_p}=\dfrac{1}{1+1/4}=\dfrac{1}{5/4}=\boxed{4/5}$

$\Rightarrow$ Não está em realimentação unitária.

$G=\dfrac{1}{s(s+1)} \Rightarrow \tilde{G}=\dfrac{G}{1+G+(3-1)}=\dfrac{\frac{1}{s(s+1)}}{\frac{s(s+1)+2}{s(s+1)}}=\dfrac{1}{\underbrace{s^2+s+2}}$

estável, tipo 0

$K_p=\lim_{s\to0}\tilde{G}(s)=\dfrac{1}{2}$

$e_d=\dfrac{1}{1+K_p}=\boxed{2/3}$

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⑥ $1+\dfrac{5}{(s+2)(s+\gamma)}=0 \Rightarrow s^2+2s+\gamma s+2s+5=0 \Rightarrow 1+\dfrac{\gamma(s+2)}{s^2+2s+5}$, $m=1 \quad z_1=-2$, $n=2 \quad p_1=-1+2j \quad p_2=-1-2j$

$n-m=1$

$D(s)=s^2+2s+5 \Rightarrow D'(s)=2s+2$

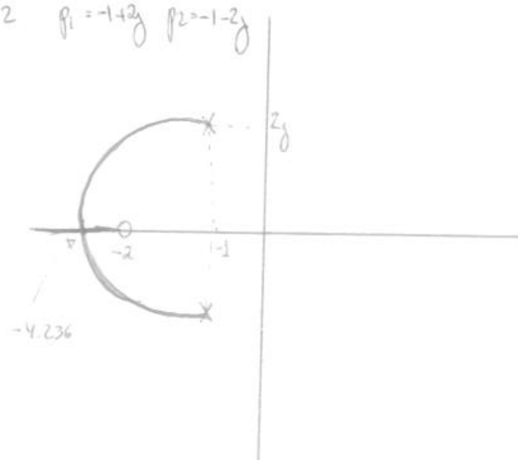
$N(s)=s+2 \Rightarrow N'(s)=1$

$D'(s)N(s)-D(s)N'(s)=0 \Rightarrow (2s+2)(s+2)-(s^2-2s+5)=0 \Rightarrow s^2+4s-1=0$

$s_1=0.236$

$s_2=-4.236$

$1+\gamma P(s)=0 \Rightarrow \gamma=1/P(-4.236)=\boxed{6.472}$



(7) - $P(s) = \dfrac{1}{s(s+3)(s+5)}$ $z=2$ $C(s) = \dfrac{K(s+z)}{(s+p)}$ pólos dominantes $-2 \pm 4j$

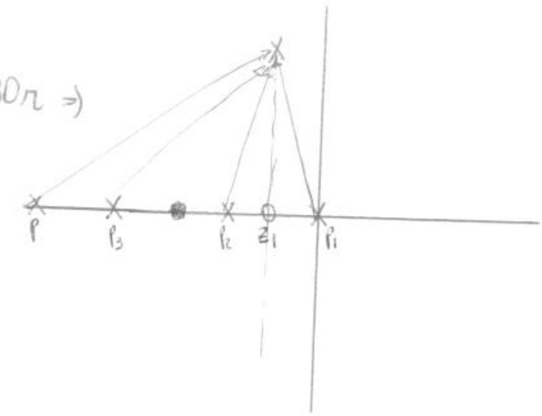
Se o $\underbrace{\text{pólo dominante}}_{-2+4j}$ pertence ao LR de $C(s)P(s)+1=0$, então pela condição de fase

$$\angle z - \angle p_1 - \angle p_2 - \angle p_3 - \angle p = 180r \Rightarrow$$

$$\angle(-2+4j-(-2)) - \angle(-2+4j) - \angle(-2+4j-(-3)) - \angle(-2+4j-(-5)) - \angle p = 180r \Rightarrow$$

$$90^\circ - 116.56^\circ - 75.96^\circ - 53.13^\circ + 180r = \angle p \Rightarrow$$

$$\angle p = -155.65 + 180 = 24.35^\circ$$



$$\tan(24.35^\circ) = \frac{4}{p-2} \Rightarrow p = 10.84$$

$$C(s) = \frac{K(s+2)}{(s+10.84)} \Rightarrow 1 + \frac{K(s+2)}{(s+10.84)(s+3)(s+5)s}\Bigg|_{s=-2+4j} = 0 \Rightarrow K = 223{,}64$$

$$\boxed{C(s) = \frac{223.64(s+2)}{(s+10.84)}}$$

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(8) $P(s) = \dfrac{s+2}{s(s+1)(s+p)}$ $p=10$, $p=16$

$\sigma_{a_1} = \dfrac{0-1-\boxed{10}+2}{2} = -4.5 \Rightarrow$ Figura $\boxed{a}$
$\sigma_{a_2} = \dfrac{0-1-\boxed{16}+2}{2} = -7.5 \Rightarrow$ Figura $\boxed{b}$
} Usando a assíntota

- Os outros dois pólos estão em $\boxed{e}$ e $\boxed{g}$.
O pólo que vem de g só chega em i (ou h) quando o pólo que está em f também chegar nesse ponto.