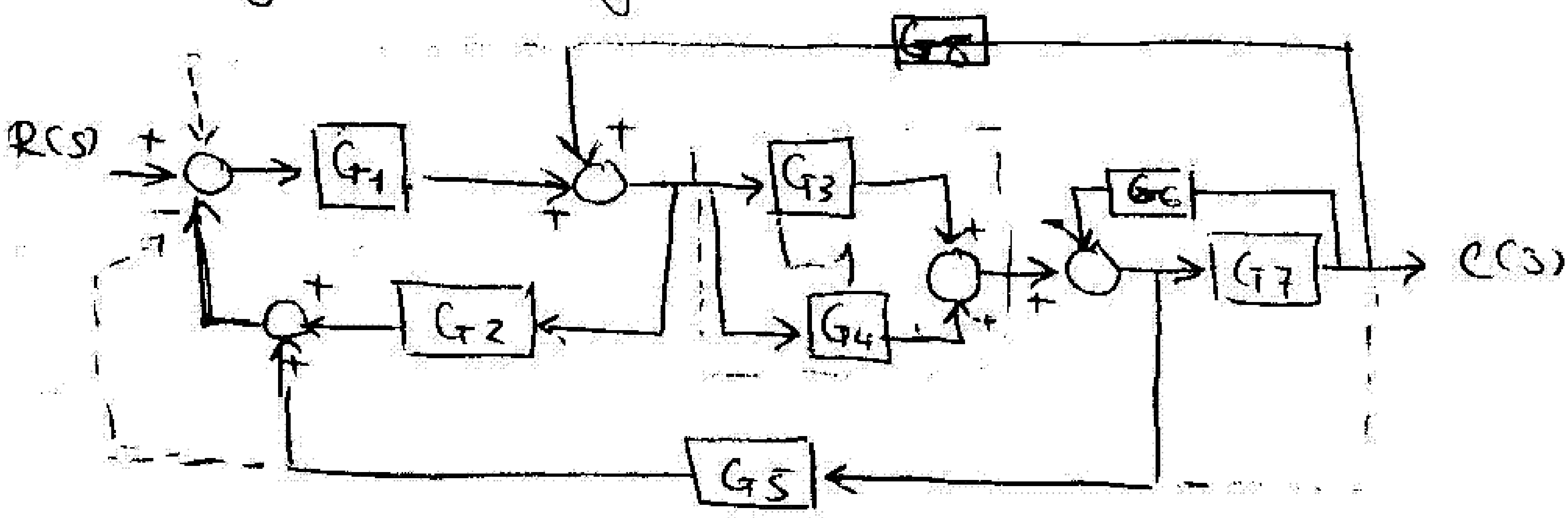
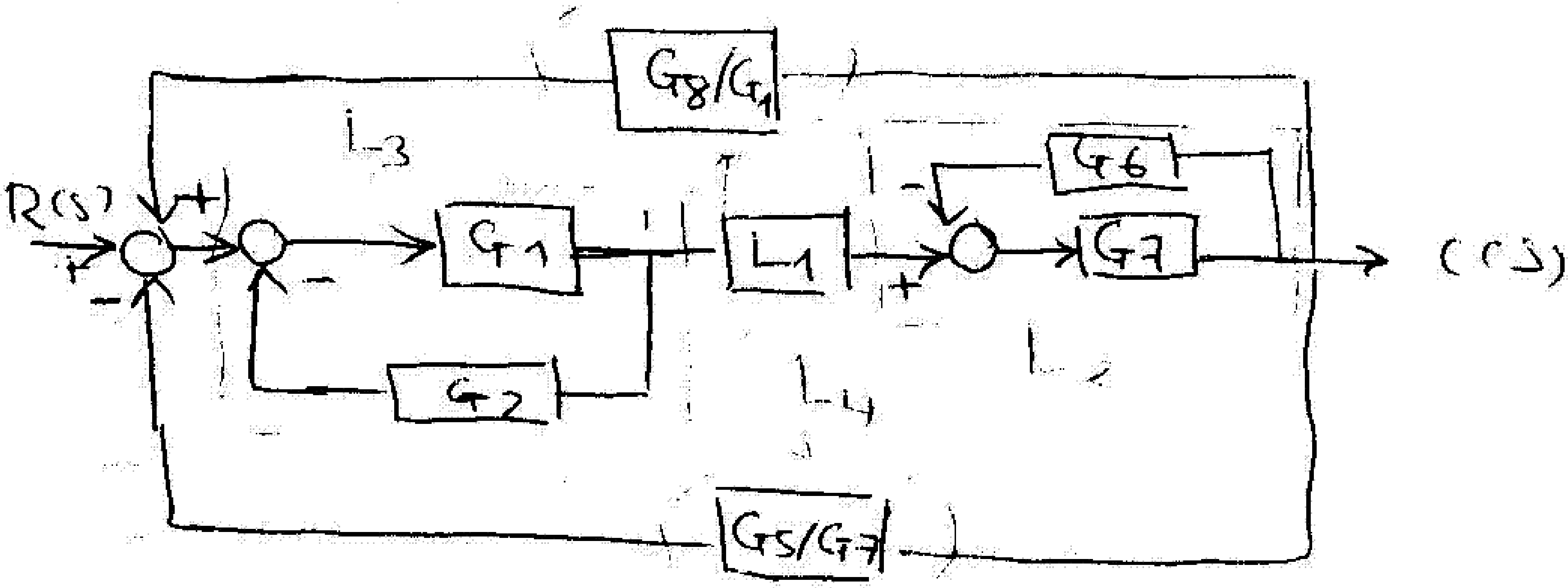
EPM308, Final Exam
2009/2010 Soln.

1. a) Using Block diagram reduction

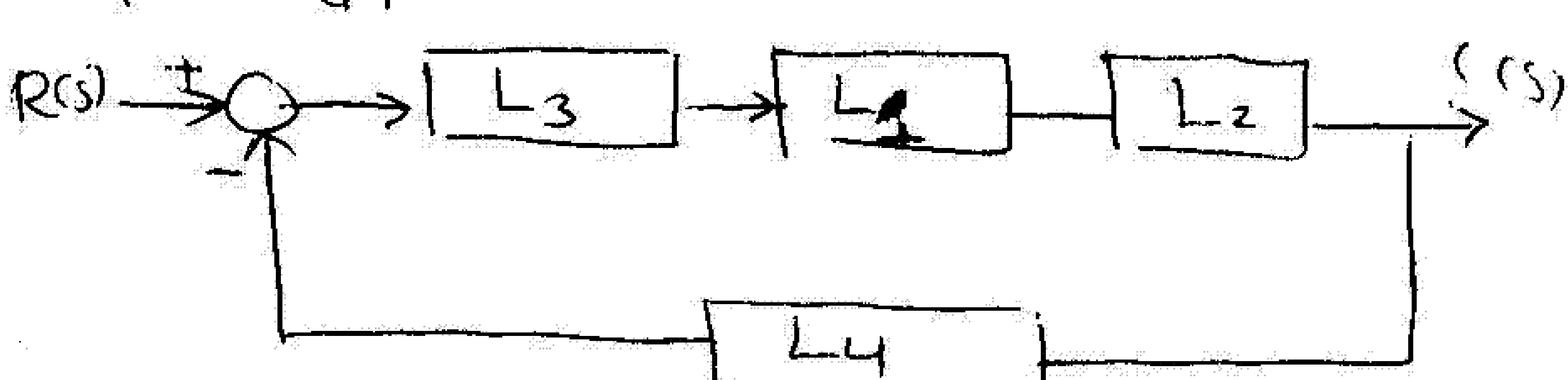


$L_1 = G_3 + G_4$



$$L_3 = \frac{G_1}{1+G_1G_2}, \quad L_2 = \frac{G_7}{1+G_6G_7},$$

$$L_4 = \frac{G_5}{G_7} - \frac{G_8}{G_1}$$



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$$G(S) = \frac{L_1 L_2 L_3}{1 + L_1 L_2 L_3 L_4}$$

$$= \frac{(G_3+G_4)\left(\frac{G_7}{1+G_6G_7}\right)\left(\frac{G_1}{1+G_1G_2}\right)}{1+(G_3+G_4)\left(\frac{G_7}{1+G_6G_7}\right)\cdot\left(\frac{G_1}{1+G_1G_2}\right)\cdot\frac{G_1G_5 - G_7}{(G_1 G_7}}$$

$$\therefore G(S) = \frac{G_1G_3G_7 + G_1G_4G_7}{1+G_1G_2+G_6G_7+G_1G_2G_6G_7 + G_1G_3G_5 + G_1G_4G_5 - G_3G_7G_8 - G_4G_7}$$

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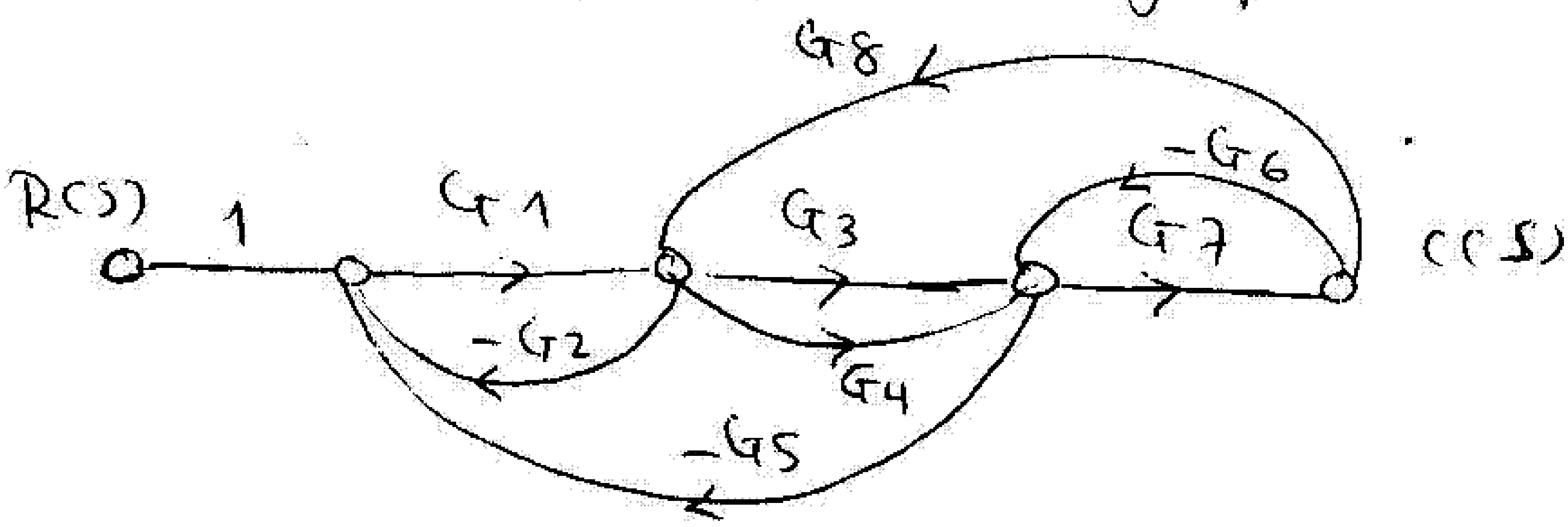
10 b) using signal flow graph & Mason's rule



Pathes: $P1: G_1 G_3 G_7$
$P2: G_1 G_4 G_7$

Loops
$L_1 = -G_1 G_2$
$L_2 = -G_1 G_3 G_5$
$L_3 = -G_1 G_4 G_5$
$L_4 = G_3 G_7 G_8$
$L_5 = -G_6 G_7$
$L_6 = G_4 G_7 G_8$

non-touching Loops L_1 & L_5

$$\Delta = 1 - (L_1 + L_2 + L_3 + L_4 + L_5 + L_6) + L_1 L_5$$

$\Delta_1 = 1$, (all loops touching Path 1)

$\Delta_2 = 1$, (all loops touching Path 1)

$$G(s) = \frac{\sum_{i=1}^{2} \Delta_i P_i}{\Delta}$$

$$= \frac{G_1 G_3 G_7 + G_1 G_4 G_7}{(1 + G_1 G_2 + G_1 G_3 G_5 + G_1 G_4 G_5 - G_3 G_7 G_8 - \ldots}$$

$+ G_6 G_7 + \ldots$

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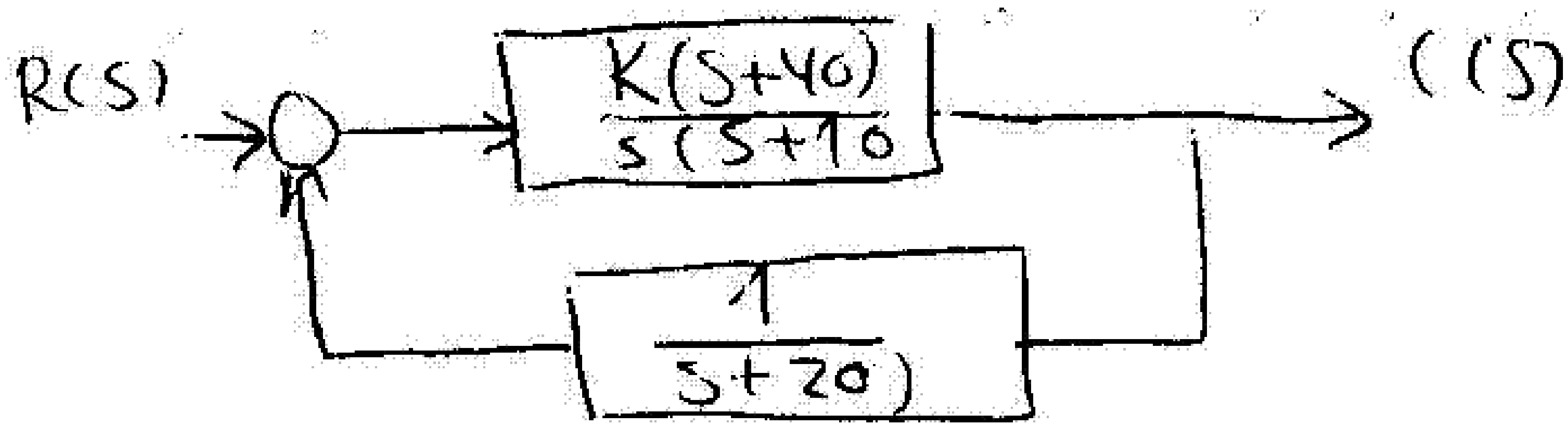
2.



$$1+GH = 1+\frac{K(S+40)}{s(S+10)}\cdot\frac{1}{(S+20)} = 0$$

$$\therefore \; S^3 + 30S^2 + (200+K)S + 40K = 0$$

i)

$$\begin{array}{c|cc}
s^3 & 1 & 200+K \\
s^2 & 30 & 40K \\
s^1 & \dfrac{-\begin{vmatrix} 1 & 200+K \\ 30 & 40K \end{vmatrix}}{30} & 0 \\
s^0 & 40K &
\end{array}$$

$$\longrightarrow \frac{-40K + 6000 + 30K}{30}$$

For a stable system;

$6000 - 10K > 0 \Rightarrow K < 600$

$40K > 0 \qquad K > 0$

$\therefore$ range for stable system

$$0 < K < 600$$

2.

ii) For a marginally stable system $K = 600$

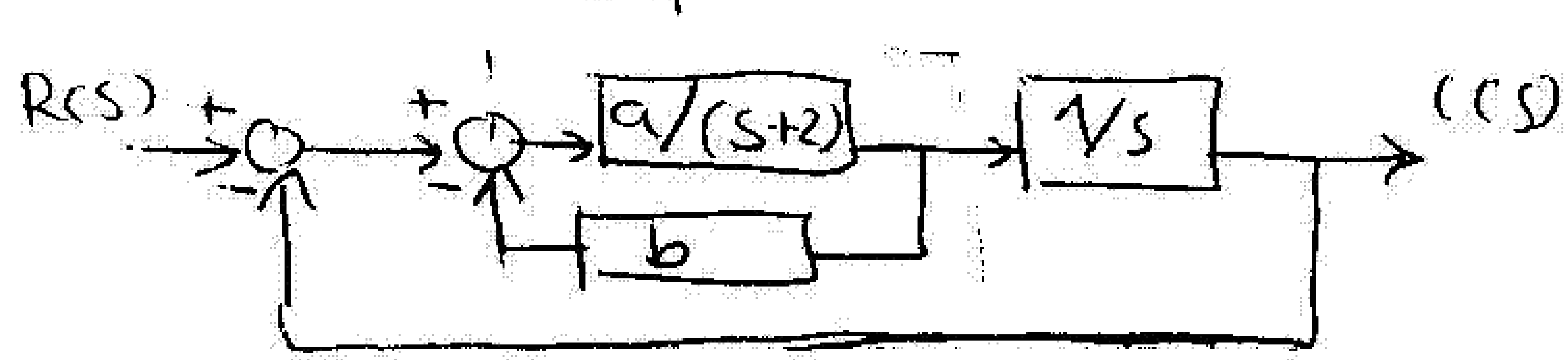
$\therefore$ for s^2

$$30\, s^2 + 40 * 600 = 0$$

$\therefore$ $s^2 = 800$ $\Rightarrow$ $s_{1,2} = \pm j\sqrt{800}$;
$= \pm j\, 20\sqrt{2}$; $\omega_n =$

1.1

3 a)



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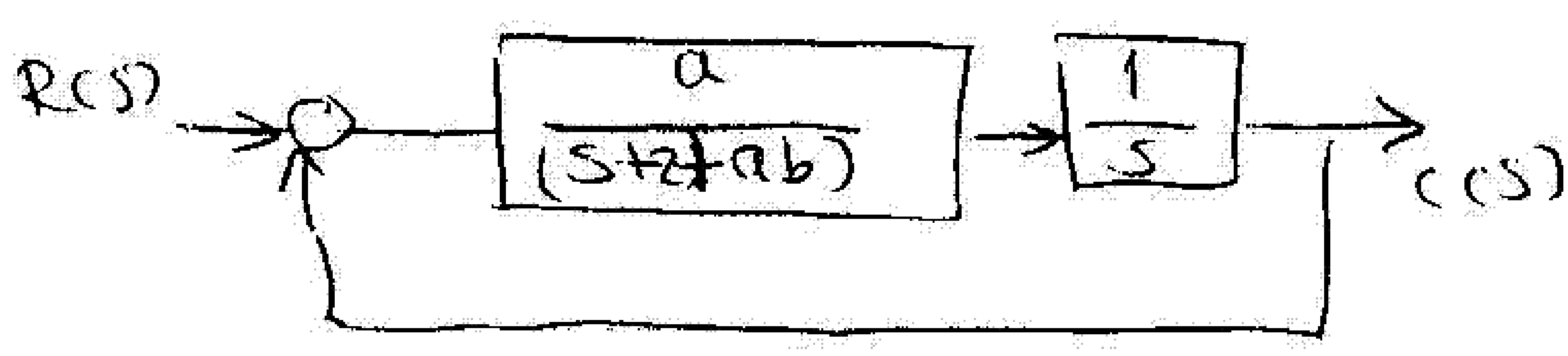
$L_1 =$

$\Downarrow$

=



$T_s = 1.4$ sec. $\%OS = 4.6\%$.

$$1 + GH = 0 \Rightarrow 1 + \frac{a}{s(s+2+ab)} = 0$$

$\therefore$ $s^2 + (2+ab)s + a = 0$

standard form $s^2 + 2\zeta\omega_n s + \omega_n^2 = 0$

$\therefore$ $a = \omega_n^2$, $2\zeta\omega_n = (2+ab)$

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$$T_s = \frac{4}{\zeta\omega_n} \Rightarrow \zeta\omega_n = \frac{4}{1.43}$$

$$\%OS = 4.6\% \Rightarrow \zeta = \frac{\ln(\%OS)^2}{\sqrt{\pi^2 + (\ln\%)^2}} = 0$$

$$\therefore \omega_n = \frac{4}{1.43 \times 0.7} = 4.$$

$$\boxed{\therefore a = \omega_n^2 = 16}$$

$$2 + ab = 2\zeta\omega_n = 2 \times 0.7 \times 4 = 5.6$$

$$\boxed{\therefore b = \frac{3.6}{16} = 0.225}$$

- Since the system is type $\underline{\mathbf{1}}$, then

$$\boxed{e_{ss}\ (\text{for unit step}) = \text{Zero}}$$

- the steady state error for unit ramp input:

$$e_{ss} = \lim_{s\to 0} \frac{s \cdot \frac{1}{s^2}}{1 + G(s)} = \lim_{s\to 0} \frac{1}{s + \frac{a}{(s + (2+ab))}}$$

$$= (2 + ab)/a$$

$$= \frac{2 + 16 \times 0.225}{16}$$

$$= 0.35$$

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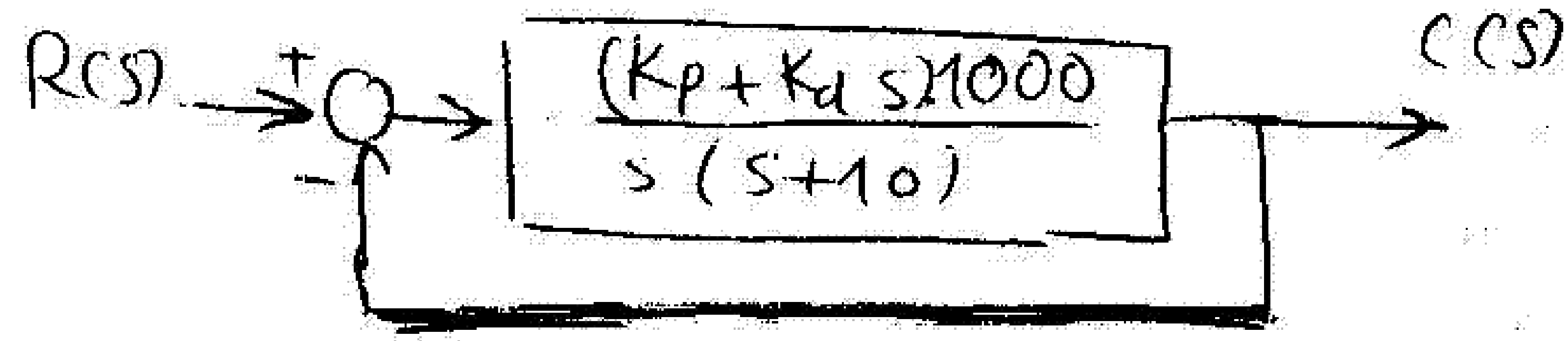
3b).



$$G_{eq}(s) = \frac{G(S)}{1+G(s).H(S)} = \frac{\frac{(K_p+K_d s)\cdot 1000}{s(s+10)}}{1+\frac{(K_p+K_d s)\,1000}{s*(s+10)}}$$

$$= \frac{1000(K_p+K_d s)}{s^2+(10+1000K_d)s+1000}$$

Since the system is type 1, then the steady st

error Constant is K_v

$\therefore$ $K_v = 1000$

$$K_v = \lim_{s\to 0} sG(s) = \frac{1000K_p}{10} = 1000$$

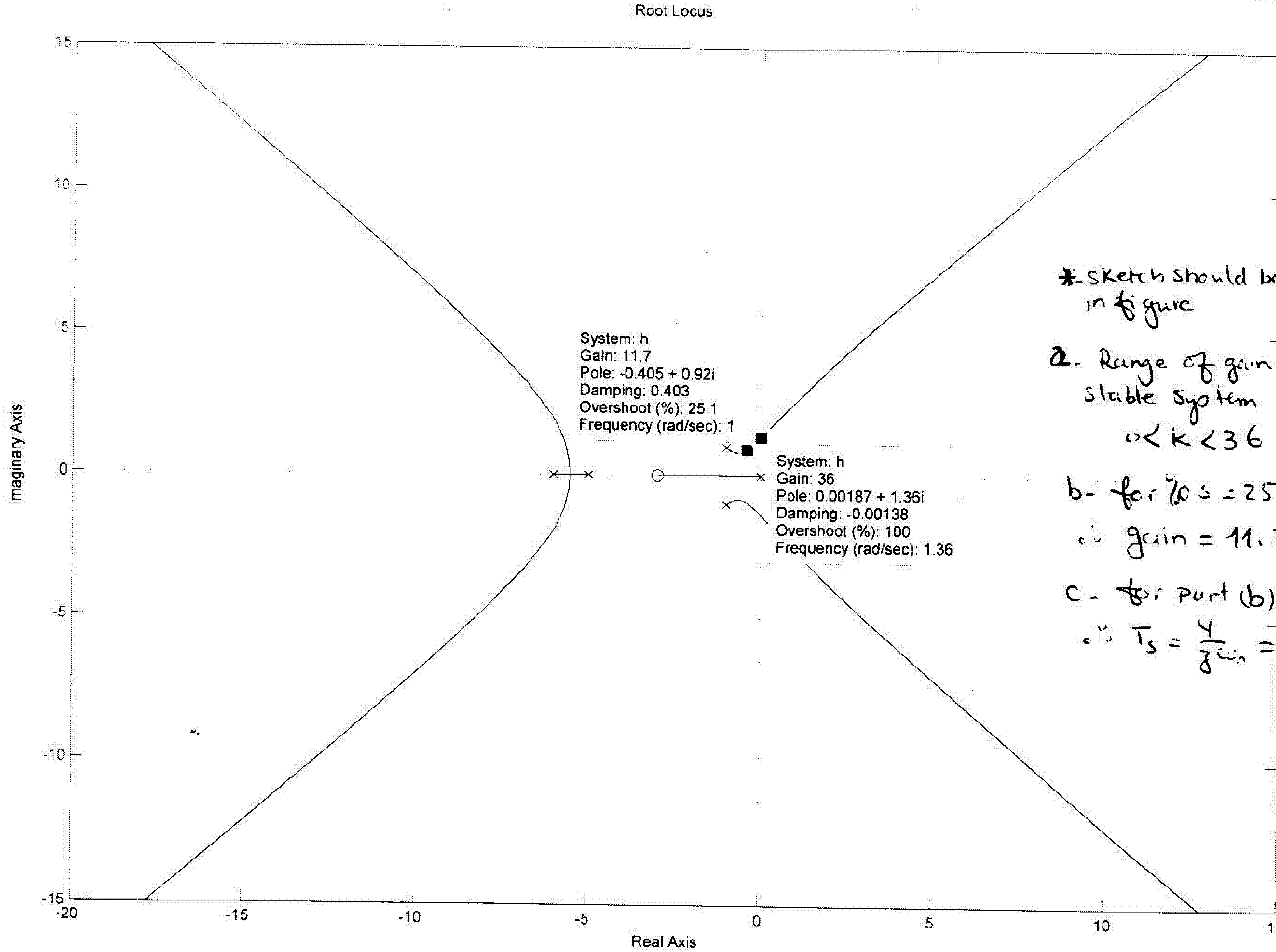
$$\boxed{\therefore\ K_p = 10}$$

for $T_s = 0.08 = \frac{4}{\zeta\omega_n} \Rightarrow \zeta\omega_n = 50$

$\therefore$ $(10+1000K_d) = 2\zeta\omega_n = 100$

$$\boxed{\therefore\ K_d = \frac{90}{1000} = 0.09}$$

Solution of Prob. 04 for Final Exam of EPM308 (Automatic Control Course), Fall 2009/2010



* sketch should be as shown in figure

a- Range of gain K for stable system

$0 < K < 36$

b- for $\%OS = 25\%$ ($\zeta = 0.40$

$\therefore$ gain $= 11.7$

c- for part (b), $\zeta\omega_n = 0.4$

$\therefore T_s = \frac{4}{\zeta\omega_n} = \frac{4}{0.405} \simeq 1$

Solution of Prob. 5 for Final Exam of EPM 308 (autom
Control course), Fall 2009/2010.

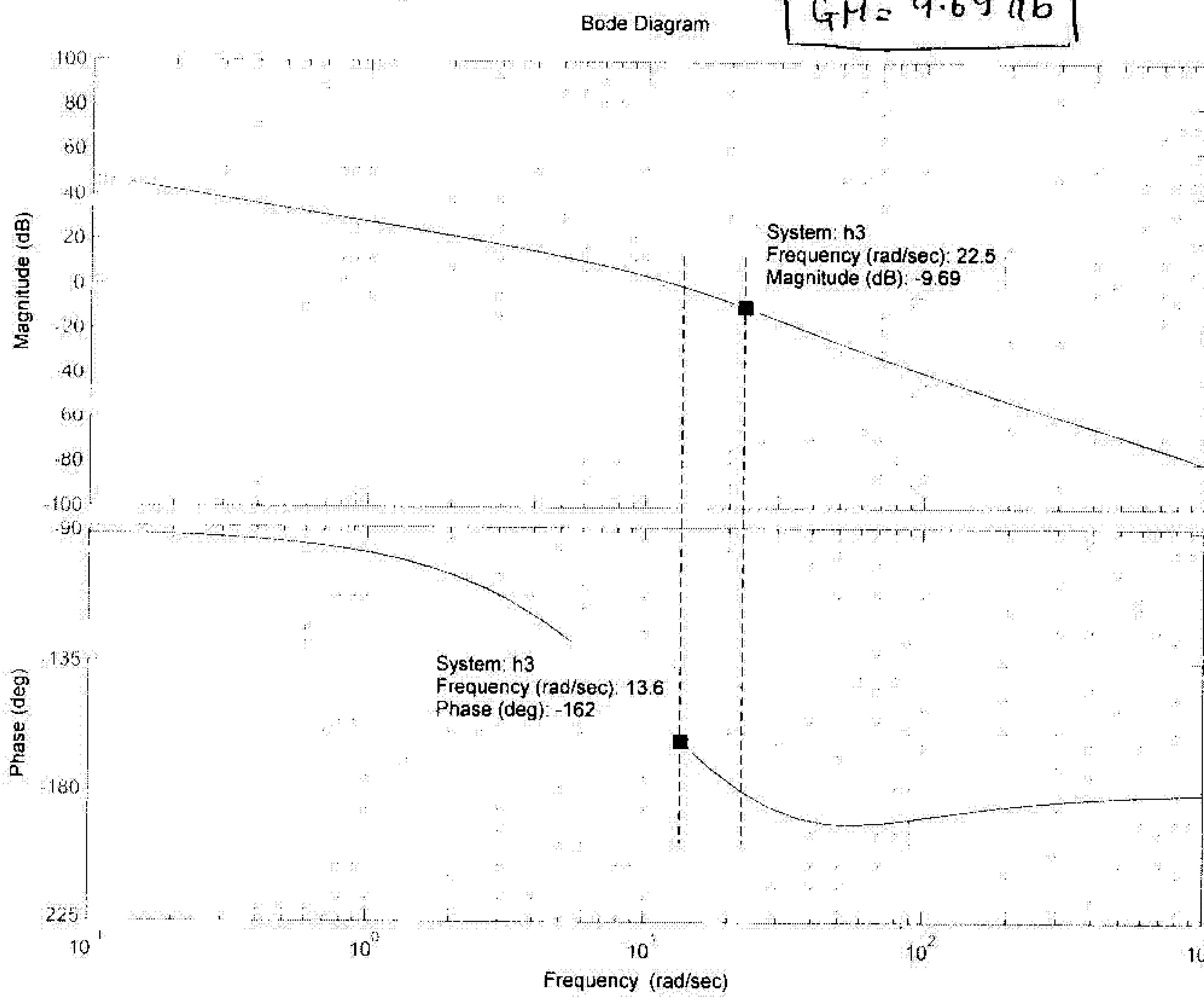
$$KGH = \frac{K(S+50)}{S(S+10)} \cdot \frac{1}{S+20}$$

$$= \frac{K \cdot 50}{10 * 20} * \frac{(S/50+1)}{S(\frac{S}{10}+1)(S/20+1)}$$

for $K = 100$

$\therefore \; K \times \frac{50}{200} = 25 \Rightarrow 20 \log 25 = 27.96$

$\boxed{GH = 9.69 \text{ db}}$



$$\boxed{\text{Phase Margin} = 180 - 162 = 18^\circ}$$