

12 Pages

1. Please give the information requested in the boxes below.
2. Enter your name in the space provided to the right, fold over and seal down (using the label provided) to hide your name.
3. The answers must be legibly written. The Examiners can either ignore illegible script or have it typed and the expense of typing charged to the candidate.
4. Write your answers in ink.
5. Begin each answer on a fresh page. Do all rough work in the answer book and cross it through.
6. No part of this book is to be torn out; it must be handed in complete.
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8. **Every book must be handed in. In no circumstances may answer books, used or unused, be taken out of the examination venue.**

1	Student Number	
2	Title of Examination Paper	Control Engineering
3	Module Code	SSEE 5014
4	Date and Time of Examination	9/1/25
5	Examination Venue	CSG
6	Seat Number	
7	Number of Answer Books handed in	

List the numbers of the questions you have attempted	Office Use
Q2	
Q3	
Q4	
Q5	
)	
Total	72.

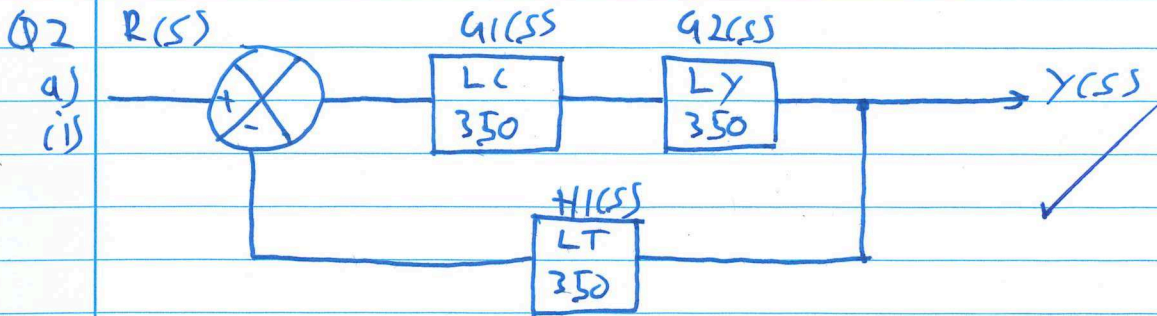
(Gweler yr ochr arall am y fersiwn Cymraeg)

Complete, fold and seal
(see note 2 below)

SURNAME: Ibrahim

FORENAME(S): Mohammed

Zee Shah



$$G_1(s) = kp$$

$$H_1(s) = \frac{1}{2s+1}$$

$$G_2(s) = \frac{0.25}{110s+1}$$

(ii) Let $G(s) = G_1(s) G_2(s)$

$$= \frac{0.25kp}{110s+1}$$

$$CLTF = \frac{G(s)}{1+G(s)H(s)}$$

$$= \frac{0.25kp}{110s+1} \div \left(1 + \left(\frac{0.25kp}{110s+1} \right) \left(\frac{1}{2s+1} \right) \right)$$

x top & bottom by $(110s+1)(2s+1)$

$$CLTF = \frac{0.25kp(2s+1)}{(110s+1)(2s+1) + 0.25kp}$$

$$= \frac{0.25kp(2s+1)}{220s^2 + 110s + 2s + 1 + 0.25kp}$$

$$= \frac{0.25kp(2s+1)}{220s^2 + 112s + 1 + 0.25kp}$$

$$\text{Sub } k_p = 1.10$$

$$CLTF = \frac{0.275(2s+1)}{220s^2 + 1125 + 1 + 0.275}$$

$$= \frac{0.55s + 0.275}{220s^2 + 1125 + 1 + 0.275}$$

$$= \frac{0.55}{220} \times \frac{s + 0.5}{s^2 + \frac{1125}{120} + \frac{1}{120} + \frac{0.275}{120}}$$

$$\text{Overall gain} = \frac{0.55}{220}$$

$$= 0.0025 \quad \checkmark$$

$$Y_{ss} = \lim_{s \rightarrow 0} \left\{ s \times \frac{1}{s} T(s) \right\} \quad \checkmark$$

$$= \lim_{s \rightarrow 0} \left\{ s \times \frac{1}{s} \frac{0.55s + 0.275}{220s^2 + 1125 + 1 + 0.275} \right\}$$

$$= \lim_{s \rightarrow 0} \left\{ \frac{0.275}{1 + 0.275} \right\}$$

$$= 0.216 \quad \times$$

$$\therefore e_{ss} = 1 - Y_{ss}$$

$$= 0.78$$

$$\underline{78\% \text{ SSE}} \quad \times$$

(14-3)

b) $Y(s) = E(s) G(s)$

$$E(s) = R(s) - Y(s) H(s)$$

Sub $E(s)$ into $Y(s)$

$$Y(s) = (R(s) - Y(s) H(s)) G(s)$$

$$Y(s) = R(s) G(s) - Y(s) H(s) G(s)$$

$$Y(s) + Y(s) G(s) H(s) = R(s) G(s)$$

$$Y(s) (1 + G(s) H(s)) = R(s) G(s)$$

$$\underline{Y(s)} = \frac{G(s)}{1 + G(s) H(s)}$$

6

Q3

$$a) G(s) = \left(\frac{2}{s+1} \right) \left(\frac{1}{s(s+3)} \right)$$

$$= \frac{2}{(s+1)(s^2+3s)}$$

$$= \frac{2}{s^3 + 3s^2 + s^2 + 3s}$$

$$= \frac{2}{s^3 + 4s^2 + 3s}$$

$$G_1(s) = \frac{G(s)}{1 + G(s)H(s)}$$

$$= \frac{2}{\frac{s^3 + 4s^2 + 3s}{1 + \frac{2}{s^3 + 4s^2 + 3s}} \times k}$$

x top & bottom by $s^3 + 4s^2 + 3s$

$$G_1(s) = \frac{2}{s^3 + 4s^2 + 3s + 2k}$$

$$a_n = 1$$

$$a_{n-1} = 4$$

$$a_{n-2} = 3$$

$$a_{n-3} = 2k$$

s^3	1	3
s^2	4	$2k$
s^1	<u>$3-2k$</u>	0
s^0	$2k$	

$$b_1 = \frac{(4 \times 3) - (1 \times 2k)}{4}$$

$$= 3 - 2k$$

$$c_1 = \frac{((3-2k) \times 0) - (4 \times 0)}{3-2k}$$

$$= 0$$

$$b_2 = \frac{[(3-2k) \times 2k] - (4 \times 0)}{3-2k}$$

$$b_2 = 2k$$

$$3-2k > 0$$

$$3 > 2k$$

$$\frac{3}{2} > k$$

$$2$$

$k < 1.5$ for system stability
X

method ok

b) For unity fb, Let $G_2(s) = \frac{G_1(s)}{1+G_1(s)}$

$$G_2(s) = \frac{2}{\frac{s^3+4s^2+3s+2k}{1} \cdot \frac{2}{s^3+4s^2+3s+2k}}$$

$$G_1(s) = ?$$

X top & bottom by $s^3+4s^2+3s+2k$

$$G_2(s) = \frac{2}{s^3+4s^2+3s+2k} (+)$$

System is class 0

(c)

(i) $s^3+10s^2+2s+9 \rightarrow$ All coefficients are present and positive, hence system can be stable

(ii) $s^5+6s^4+9s^3+2s^2-s+4 \rightarrow$ negative coefficient + present, hence system is unstable

(iii) $s^4+7s^3+s^2+5 \rightarrow$ All coefficients are positive but 1 is missing, therefore system is at best critically stable.

Q4.

$$a) T(s) = \frac{G(s)}{1 + G(s) \times 1}$$

$$= \frac{25}{\frac{s(s+4)}{1 + \frac{25}{s(s+4)}}}$$

x to & Bottom by $s(s+4)$

$$T(s) = \frac{25}{s(s+4) + 25}$$

$$T(s) = \frac{25}{s^2 + 4s + 25}$$

$$(i) \omega_n^2 = 25$$

$$\omega_n = 5 \text{ rad/s}$$

$$\text{Compare with } \frac{k\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$(ii) 2\zeta\omega_n = 4$$

$$\zeta = \frac{4}{2 \times 5}$$

$$\zeta = \frac{4}{10}$$

$$\zeta = 0.4$$

$$(iii) \omega = \omega_n \sqrt{1 - \zeta^2}$$

$$\omega = 5 \sqrt{1 - 0.4^2}$$

$$\omega = 4.58 \text{ rad/s}$$

$$(iv) t_r = \pi - \tan^{-1} \left(\frac{\sqrt{1 - \zeta^2}}{\zeta} \right) = \pi - \tan^{-1} \left(\frac{\sqrt{1 - 0.4^2}}{0.4} \right)$$

$$t_r = \frac{\omega_n \sqrt{1 - \zeta^2}}{\omega_n \sqrt{1 - 0.4^2}}$$

$$t_r = 0.93 \text{ sec}$$

$$(v) t_p = \frac{t_c}{\omega_n \sqrt{1-\zeta^2}}$$

$$t_p = \frac{t_c}{5\sqrt{1-0.4^2}}$$

$$t_p = 0.69 \text{ sec}$$

$$(vi) \% \text{ O/S} = 100 e^{\frac{-\zeta \pi}{\sqrt{1-\zeta^2}}}$$

$$\% \text{ O/S} = 100 e^{\frac{-0.4\pi}{\sqrt{1-0.4^2}}}$$

$$\% \text{ O/S} = 25.38\%$$

$$(vii) \text{ Settling time (2\%)} \quad t_s = \frac{4}{\zeta \omega_n}$$

$$t_s = \frac{4}{0.4 \times 5}$$

$$t_s = 2 \text{ sec}$$

$$(viii) h = \frac{2}{\pi} \sqrt{\frac{1-\zeta^2}{\zeta^2}}$$

$$h = \frac{2}{\pi} \sqrt{\frac{1-0.4^2}{0.4^2}}$$

$$h = 1.46$$

(c) a From CLTF denominator:

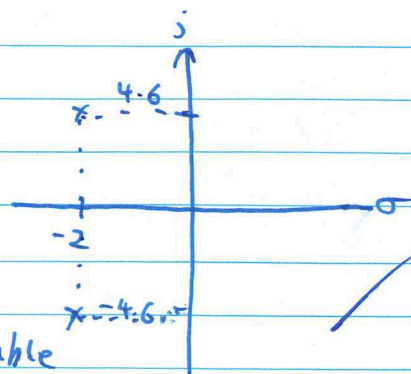
$$a=1, b=4, c=25$$

$$\therefore s = \frac{-4 \pm \sqrt{(4)^2 - 4(1)(25)}}{2}$$

$$s = -2 + j4.6$$

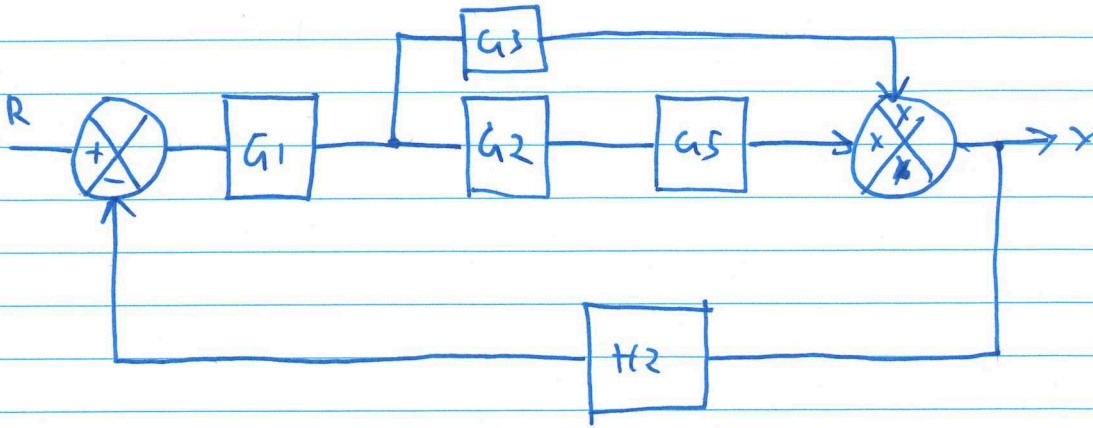
$$s = -2 - j4.6$$

System is stable

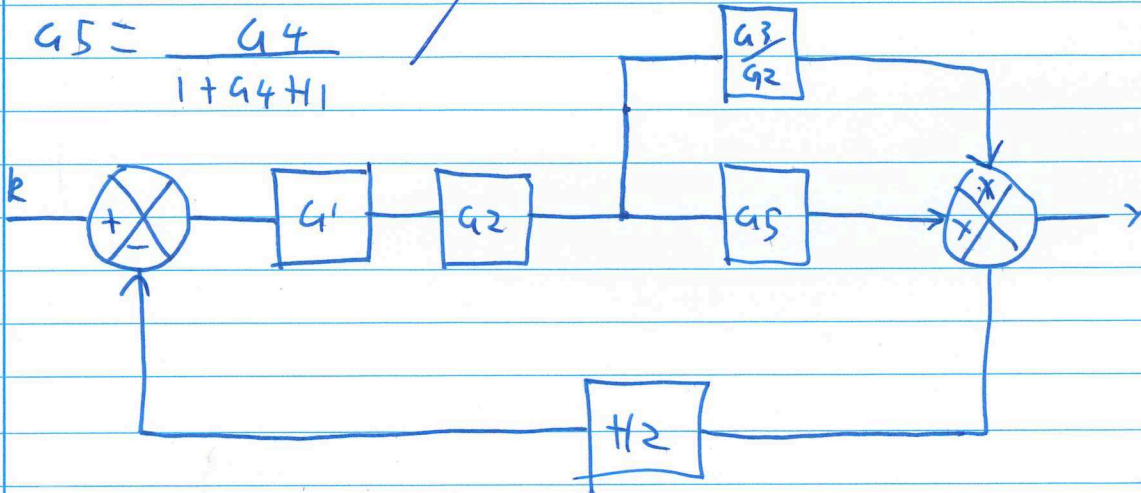


Q5.

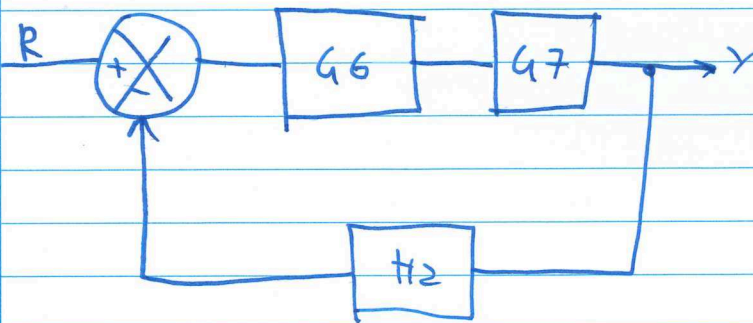
a)



$$G_5 = \frac{G_4}{1 + G_4 H_1}$$



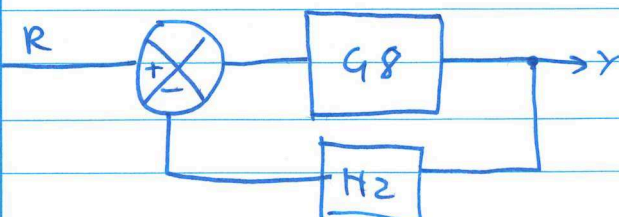
2



$$G_6 = G_1 G_2 \quad \times$$

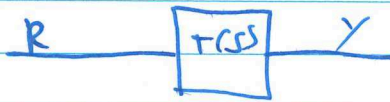
$$G_7 = \frac{G_3}{G_2} + G_5 \quad \checkmark$$

1



$$G_8 = G_6 G_7 \quad \checkmark$$

2



$$T(s) = \frac{G_8}{1 + G_8 H_2} \quad \checkmark$$

$$= \frac{G_6 G_7}{1 + G_6 G_7 H_2}$$

$$= \frac{G_1 G_2 G_7}{1 + G_1 G_2 G_7 H_2}$$

$$= \frac{G_1 G_2 \left(\frac{G_3}{G_2} + G_5 \right)}{1 + G_1 G_2 \left(\frac{G_3}{G_2} + G_5 \right) H_2}$$

$$= \frac{G_1 G_2 \left(\frac{G_3}{G_2} + \frac{G_4}{1 + G_4 H_1} \right)}{1 + G_1 G_2 \left(\frac{G_3}{G_2} + \frac{G_4}{1 + G_4 H_1} \right) H_2}$$

$$= \frac{\cancel{G_1 G_3} + \cancel{G_1 G_2 G_4}}{1 + \cancel{G_1 G_3} + \cancel{G_1 G_2 G_4} H_2}$$

$$= \frac{G_1 G_3 + \frac{G_1 G_2 G_4}{1 + G_4 H_1}}{1 + \left(\frac{G_1 G_3 + \frac{G_1 G_2 G_4}{1 + G_4 H_1}}{1 + G_4 H_1} \right) H_2}$$

X

$$b) \quad T(s) = \frac{8 + \frac{4}{s+1} \left(\frac{1}{s} \right)}{1 + \frac{2}{s}}$$

✓

method check

$$\frac{1 + G_1 G_3 H_2 + G_1 G_2 G_4 H_2}{(1 + G_4 H_1)}$$

1

1

$$T(s) = 8 + \frac{\left(\frac{4}{s+1}\right)\left(\frac{1}{s}\right)}{\frac{2s+1}{s}}$$

$$1 + 8 + \frac{\left(\frac{4}{s+1}\right)\left(\frac{1}{s}\right)}{1 + \frac{2s+1}{s}}$$

$$T(s) = 8 + \frac{\left(\frac{4}{s+1}\right)}{3}$$

$$1 + 8 + \frac{\left(\frac{4}{s+1}\right)}{3}$$

method
check.

$$T(s) = 2.67 + \frac{12}{s+1}$$

$$9 + \frac{12}{s+1}$$

x top & bottom by $\frac{12}{s+1}$

$$T(s) = \frac{2.67(s+1) + 12}{9(s+1) + 12}$$

$$T(s) = \frac{2.67s + 14.67}{9s + 21}$$

X