



Examination Answer Books

12 Pages

Instructions to Candidates

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.
7. If more books than one are used, fasten them together using the tags available from the invigilator(s).
8. Every book must be handed in. In no circumstances may answer books, used or unused, be taken out of the examination venue.

Complete, fold and seal
(see note 2 below)

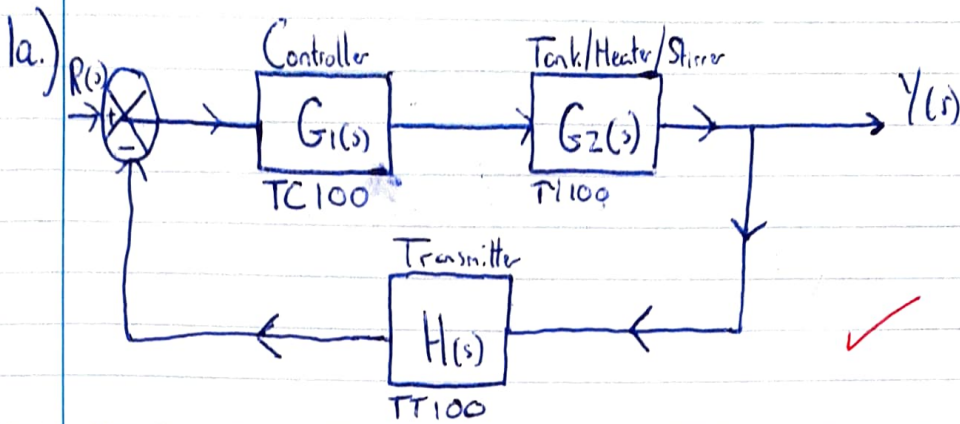
SURNAME: SMITHAM

FORENAME(S): AERON

1	Student Number	2017197
2	Title of Examination Paper	Control Engineering
3	Module Code	SGEE5009
4	Date and Time of Examination	18/5/23 09.30
5	Examination Venue	Coleg Sir Ger Gralg
6	Seat Number	12
7	Number of Answer Books handed in	

List the numbers of the questions you have attempted	Office Use
1	9
2	20
3	25
5	7
Total	61

Mark checked and
agreed
L Williams



$$G_{1(s)} = K_p$$

$$G_{2(s)} = \frac{0.5}{60s+1}$$

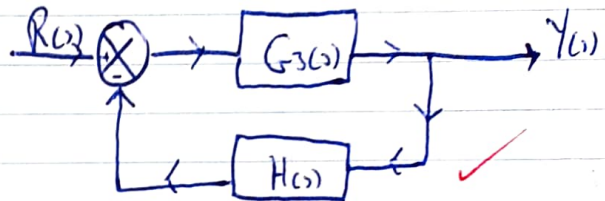
$$H(s) = \frac{1}{8s+1} = \frac{1}{8s+1}$$

1b.)

$$G_{3(s)} = G_{1(s)} \times G_{2(s)}$$

$$= K_p \times \frac{0.5}{60s+1}$$

$$= \frac{0.5K_p}{60s+1}$$



$$T(s) = \frac{G_{3(s)}}{1 + H(s)G_{3(s)}}$$

$$= \frac{0.5K_p / 60s+1}{1 + (1/8s+1) \cdot (0.5K_p / 60s+1)}$$

0.5Kp/ missing

Multiply top and bot by $(8s+1)$ and $(60s+1)$

$$T(s) = \frac{0.5K_p(8s+1)}{(8s+1)(60s+1) + 1}$$

0.5Kp

$$= \frac{4K_p(s+0.125)}{480s^2 + 8s + 60s + 1 + 1}$$

x

$$= \frac{4K_p(s+0.125)}{480s^2 + 68s + 2}$$

↑ $(1 + 0.5K_p)$

1b) $\div$ top and bot by 480
Cont.)

$$T(s) = \frac{0.0083k_p(s + 0.125)}{s^2 + 0.1416s + 0.0042}$$

When $k_p = 0.6$

$$T(s) = \frac{0.0083(0.6)(s + 0.125)}{s^2 + 0.1416s + 0.0042}$$

$$= \frac{0.00498(s + 0.125)}{s^2 + 0.1416s + 0.0042}$$

$$= \frac{0.00498s + 0.00062}{s^2 + 0.1416s + 0.0042}$$

error
carried
forward

overall gain ? = 0.00498

$$y_{ss} = ?$$

$$e_{ss} = ?$$

1 (c) ?

2

1

$$2a) \quad \frac{Y(s)}{R(s)} = \frac{G(s)}{1 + H(s)G(s)}$$

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

where $H(s) = 1$

Multiply top and bot by $s(s+1)$

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

$$\frac{Y(s)}{R(s)} = \frac{25}{s^2 + s + 25}$$

$$2b) \quad \frac{Y(s)}{R(s)} = \frac{W_n^2}{s^2 + 2\zeta W_n s + W_n^2}$$

$$i) \quad W_n^2 = 25$$

$$W_n = \sqrt{25}$$

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

$$ii) \quad 2\zeta W_n = 1$$

$$\therefore \zeta = \frac{1}{2W_n}$$

$$\zeta = 0.1$$

$$iii) \quad W = W_n \sqrt{1 - \zeta^2}$$

$$= 5 \sqrt{1 - 0.1^2}$$

$$= 4.975 \text{ rad/s}$$

$$iv) \quad t_r = \frac{\pi - \tan^{-1}(\sqrt{1 - \zeta^2}/\zeta)}{W}$$

$$= \frac{\pi - \tan^{-1}(\sqrt{1 - 0.1^2}/0.1)}{4.975}$$

$$= 0.336 \text{ sec}$$

(4)

(1)

(1)

(2)

(2)

(2)

2b) d

cont.)

$$v) t_p = \frac{\pi}{\omega}$$

$$= \frac{\pi}{4.975}$$

$$= 0.631 \text{ secs}$$

$$\begin{aligned} vi) \%OS &= 100 \times e^{-\frac{3\pi}{\sqrt{1-0.1^2}}} \\ &= 100 \times e^{-\frac{3\pi}{\sqrt{1-3^2}}} \\ &= 100 \times e^{-0.1 \times \pi / \sqrt{1-0.1^2}} \\ &= 72.92\% \end{aligned}$$

$$vii) t_s = \frac{4}{3\omega_n}$$

$$= \frac{4}{0.1 \times 5}$$

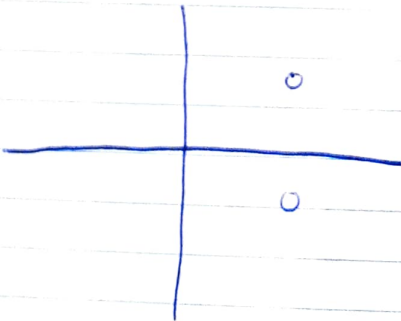
$$= 8 \text{ secs}$$

$$viii) n = \frac{2}{\pi} \sqrt{\frac{1}{3^2} - 1}$$

$$= \frac{2}{\pi} \sqrt{\frac{1}{0.1^2} - 1}$$

$$= 6.33$$

2c)



The system is unstable as the poles are in the RH plane.

X

3a)i) $s^3 + 4s^2 + 3s + 5$

This system can be stable, as all coefficients are present and positive. ✓

ii) $s^5 + 5s^4 + 3s^3 + s^2 - 4s + 1$

This system can be unstable, as the s^1 coefficient is negative. ✓

iii) $s^4 + 2s^3 + s^2 + 1$

At best this system could be critically stable, as not all the coefficients are present, but they are all positive. ✓

3b) $G_o(s) = \frac{3}{s+2} \times \frac{1}{s(s+4)}$

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

$$= \frac{3}{s(s^2 + 6s + 8)}$$

$$= \frac{3}{s^3 + 6s^2 + 8s}$$

$$G(s) = \frac{G_o(s)}{1 + H_s G(s)}$$

where $H(s) = k$

$$= \frac{3/s^3 + 6s^2 + 8s}{1 + k(3/s^3 + 6s^2 + 8s)}$$

Multiply top & bot by $(s^3 + 6s^2 + 8s)$

$$G(s) = \frac{3}{s^3 + 6s^2 + 8s + 3k}$$

$$a_n = 1$$

$$a_{n-1} = 6$$

$$a_{n-2} = 8$$

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

3

2

2

$$3b) \begin{array}{c|cc} s^3 & a_n & a_{n-2} \\ s^2 & a_{n-1} & a_{n-3} \\ s^1 & b_1 & b_2 \\ s^0 & c_1 & c_2 \end{array}$$

$$a_n = 1$$

$$a_{n-1} = 6$$

$$a_{n-2} = 8$$

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

(1)

$$b_1 = a_{n-2} - \frac{a_n}{a_{n-1}} \times a_{n-3}$$

$$= 8 - \frac{1}{6} \times 3k$$

$$= 7.5k \quad 8 - 0.5k$$

$$b_2 = a_{n-4} - \frac{a_n}{a_{n-1}} \times a_{n-5}$$

$$= 0 - \frac{1}{6} \times 0$$

$$= 0$$

$$c_1 = a_{n-3} - \frac{a_{n-1}}{b_1} \times b_2$$

$$= 3k - \frac{6}{7.5k} \times 0$$

$$= 3k$$

$$c_2 = a_{n-5} - \frac{a_{n-1}}{b_1} \times b_3$$

$$= 0 - \frac{6}{7.5k} \times 0$$

$$= 0$$

$$\begin{array}{c|cc} s^3 & 1 & 8 \\ s^2 & 6 & 3k \\ s^1 & 8-0.5k & 0 \\ s^0 & 3k & 0 \end{array}$$

For the system to be stable, there must not be a sign change in column 1. $\therefore 8-0.5k$ must be positive.

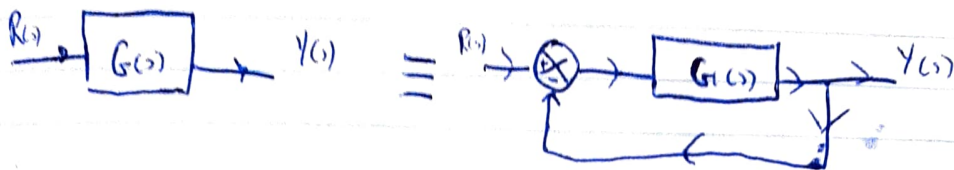
$$8-0.5k > 0$$

$$k < 16$$

(8)

(3)

3c)



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

$$G(s) = G(s)(1 + G(s))$$

$$= G(s) + G(s)G(s)$$

$$G(s) = G(s) - G(s)G(s)$$

$$= G(s)(1 - G(s))$$

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

$$G(s) = G(s)(1 + G(s))$$

$$= G(s) + G(s)G(s)$$

$$G(s) = G(s) - G(s)G(s)$$

$$= G(s)(1 - G(s))$$

$$G(s) = \frac{G(s)}{1 - G(s)}$$

Sub $G(s)$ in from part (b).

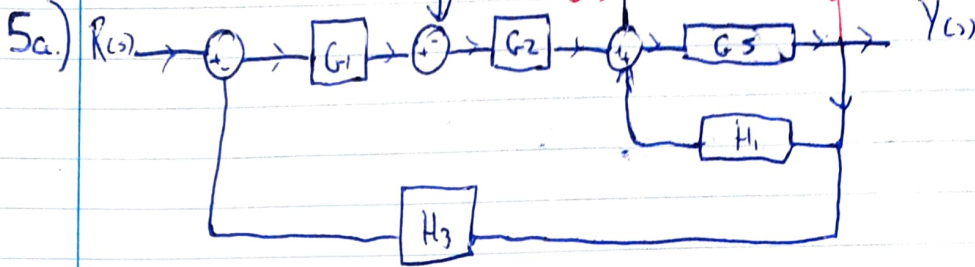
$$G(s) = \frac{3/s^3 + 6s^2 + 8s + 3k}{1 - 3/s^3 + 6s^2 + 8s + 3k}$$

Multiply top and bot by $s^3 + 6s^2 + 8s + 3k$

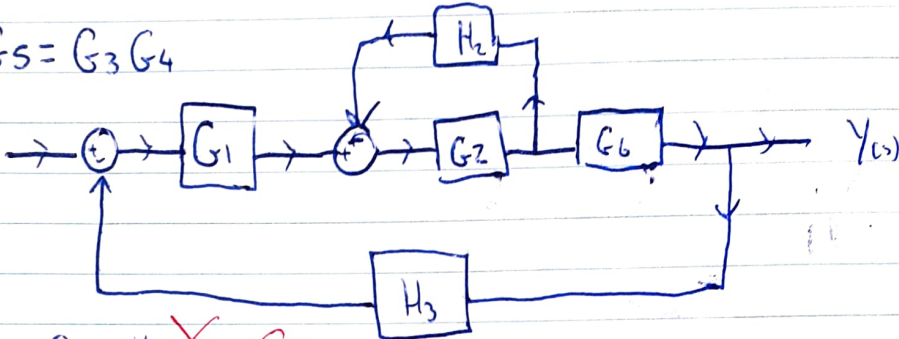
$$G(s) = \frac{3}{s^3 + 6s^2 + 8s + 3k - 3}$$

$$= \frac{3}{s^3 + 6s^2 + 8s + 3(k-1)}$$

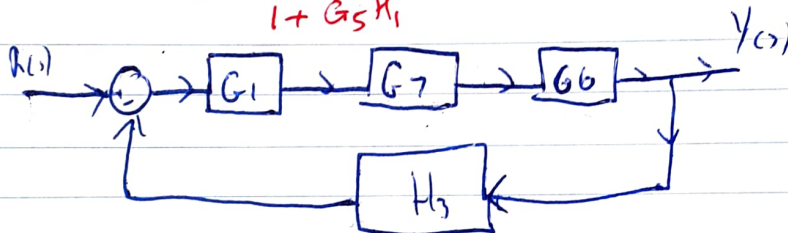
As there is no independent term of s^0 , then the class is zero.



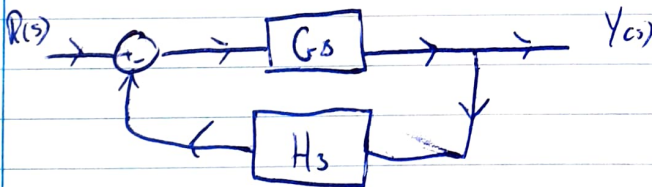
$$G_5 = G_3 G_4$$



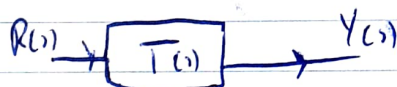
$$G_6 = G_5 + H_1 \times \frac{G_5}{1 + G_5 H_1}$$



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



$$G_8 = G_1 G_6 G_7$$



$$\begin{aligned} T(s) &= \frac{G_8}{1 + H_3 G_8} \\ &= \frac{G_1 G_6 G_7}{1 + H_3 G_1 G_6 G_7} \\ &= \frac{G_1 G_6 \left(\frac{G_2}{1 + H_2 G_2} \right)}{1 + H_3 G_1 G_6 \left(\frac{G_2}{1 + H_2 G_2} \right)} \end{aligned}$$

1

$$S_a) \frac{G_1 G_2 G_3}{1 + H_2 G_2 + H_3 G_1 G_2 G_3}$$

$$T(s) = \frac{G_1 G_2 (Gs + H_1)}{1 + H_2 G_2 + H_3 G_1 G_2 (Gs + H_1)}$$

$$= \frac{G_1 G_2 Gs + H_1 G_1 G_2}{1 + H_2 G_2 + H_3 G_1 G_2 Gs + H_1 H_3 G_1 G_2}$$

$$T(s) = \frac{G_1 G_2 G_3 G_4 + H_1 G_1 G_2}{1 + H_2 G_2 + H_3 G_1 G_2 G_3 G_4 + H_1 H_3 G_1 G_2}$$

X

$$5b) T(s) = \frac{\left(2 \times \frac{1}{s+1} \times 3 \times \frac{1}{s}\right) + \left(2 \times 2 \times \frac{1}{s+1}\right)}{1 + \left(\frac{1 \times \frac{1}{s+1}}{\cancel{s+1}}\right) + \left(\frac{1 \times \frac{1}{s+1}}{\cancel{s+1}}\right) + \left(1 \times \frac{2}{s+1} \times \frac{1}{s} \times 3 \times \frac{1}{s}\right) + \left(\frac{2 \times 1 \times 2 \times 1}{s+1}\right)}$$

$$= \frac{\frac{6}{s(s+1)} + \frac{4}{s+1}}{1 + \left(\frac{1}{s+1}\right) + \left(\frac{6}{s(s+1)}\right) + \left(\frac{4}{s+1}\right)}$$

error in
formula
carried
through

x by $s(s+1)$

$$T(s) = \frac{6 + 4s}{s(s+1) + s + 6 + 4s}$$

$$= \frac{6 + 4s}{s^2 + s + s + 6 + 4s}$$

$$T(s) = \frac{4s + 6}{s^2 + 6s + 6}$$

good method

X

5c)

Zeros

$$4s + 6 = 0$$

$$= \frac{-6 \pm \sqrt{6^2 - 4 \times 4 \times 0}}{2 \times 4}$$

$$= \frac{-6 \pm \sqrt{36 - 0}}{8}$$

$$= -0.75 \pm 0.75$$

Poles

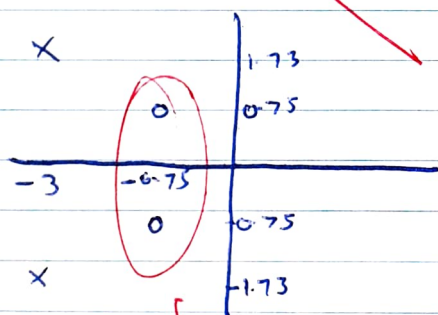
$$s^2 + 6s + 6 = 0$$

$$= \frac{-6 \pm \sqrt{6^2 - 4 \times 1 \times 6}}{2 \times 1}$$

$$= \frac{-6 \pm \sqrt{36 - 24}}{2}$$

$$= \frac{-6 \pm 3.46}{2}$$

$$= -3 \pm 1.73$$



no j term

both lie on the real axis

one real pole @ -1.5

Stable?

there is one zero according to you TF.

$$4s + 6 = 0$$

$$s = -\frac{6}{4} = -1.5$$

(2)