



Complete, fold and seal
(see note 2 below)

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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.**

1	Student Number	
2	Title of Examination Paper	Control Engineering
3	Module Code	SGEE5009
4	Date and Time of Examination	9:30 18.5.23
5	Examination Venue	Sir Gar
6	Seat Number	
7	Number of Answer Books handed in	

List the numbers of the questions you have attempted	Office Use
2	13
3	16
Total	~~28~~

Mark checked and
agreed
L Williams

a.)

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

$$H(s) = 1$$

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

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

$$\begin{aligned} \frac{Y(s)}{R(s)} &= \frac{25}{s(s+1) + 25} \\ &= \frac{25}{s^2 + s + 25} \end{aligned}$$

$s \times 1 = s$

$\frac{K\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$

Using the formula

$$\frac{K\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$



b.)

(i)
Natural frequency

$$\omega_n^2 = 25$$

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

(ii)

Damping factor

$$2\zeta\omega_n = 1$$

$$\zeta = 1/2\omega_n$$

$$\zeta = \frac{1}{2 \times 5}$$

$$\zeta = 0.1$$

(iii)

Damped frequency

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

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

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

(2)

(Vii)

$$\tau_s = \frac{4}{\pi} \times \sqrt{\frac{4}{0.1} - 1}$$

$$= 8 \text{ seconds} \quad \checkmark$$

(2)

$$\frac{\pi}{3\omega_n}$$

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

$$= 6.283 \quad \checkmark$$

(2)

a.

(i)

All coefficients are present, none are negative therefore the system is stable ✓

(ii)

All coefficients are present, one is negative therefore the system is unstable ✓

(iii)

Not all coefficients are present therefore the system at best is critically stable. ✓

$$G_0(s) = \frac{\cancel{3} \times \cancel{1}}{(s+2)\cancel{s}(s+4)} \times \frac{3}{(s+2)} \times \frac{1}{s(s+4)} \quad \checkmark$$

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

$$= \frac{3}{s(s^2 + 1.5s + 4)} \quad \begin{matrix} 2+4 = 6 \\ 2 \times 4 = 8 \end{matrix}$$

$$= \frac{3}{(s^3 + 1.5s^2 + 4s)} \quad \times \quad \begin{matrix} G_s = G_0(s) \\ 1 + G_0(s)H(s) \end{matrix}$$

$$H(s) = \cancel{4}K$$

From denominator

$$a_n = 1$$

$$a_{n-1} = 1.5$$

$$a_{n-2} = 4$$

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

$$G(s) = \frac{3/s^3 + 1.5s^2 + 4s}{1 + K \times 3/s^3 + 1.5s^2 + 4s}$$

$$= \frac{3}{s^3 + 1.5s^2 + 4s + 3K}$$

From denominator

$$a_n = 1$$

$$a_{n-1} = 1.5$$

$$a_{n-2} = 4$$

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

error
carried
forward

$$b_1 = a_{n-2} - \left(\frac{a_n}{a_{n-1}} \right) \times a_{n-3}$$

$$= 4 - \frac{1}{1.5} \times 3K$$

$$= 4 - 2K$$

$$= \underline{\underline{2K}}$$

error
cancelled

(2)

$$b_2 = a_{n-4} - \left(\frac{a_n}{a_{n-1}} \right) \times a_{n-5}$$

$$0 - \left(\frac{1}{1.5} \right) \times 0$$

$$= 0$$

✓

(2)

$$c_1 = a_{n-3} - \left(\frac{a_n}{b_1} \right) \times b_2$$

$$= 3K - \frac{1}{4 - 2K} \times 0$$

$$= 3K$$

✓

(2)

$$c_2 = a_{n-5} - \left(\frac{a_n}{b_1} \right) \times b_3$$

$$= 0 - \left(\frac{1}{4 - 2K} \right) \times 0$$

$$= 0$$

✓

(2)

$$\begin{array}{c} S_3 \\ S_2 \\ S_1 \\ S_0 \end{array} \begin{array}{|c|c|} \hline a_n & a_{n-2} \\ \hline a_{n-1} & a_{n-4} \\ \hline b_1 & b_2 \\ \hline c_1 & c_2 \\ \hline \end{array} = \begin{array}{c} S_3 \\ S_2 \\ S_1 \\ S_0 \end{array} \begin{array}{|c|c|} \hline 1 & 4 \\ \hline 1.5 & 3K \\ \hline 2K-2K & 0 \\ \hline 3K & 0 \\ \hline \end{array}$$

end
cancel

1

$K > ?$

$K < ?$