

SURNAME: Thomas

FORENAME(S): Liam

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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1	Student Number	P143797
2	Title of Examination Paper	Instrumentation & Control
3	Module Code	M7x01643
4	Date and Time of Examination	18/05/18 3:00PM
5	Examination Venue	Townhill Gym
6	Seat Number	6083
7	Number of Answer Books handed in	1

[illegible]

(Gweler yr ochr arall am y fersiwn Cymraeg)

86%

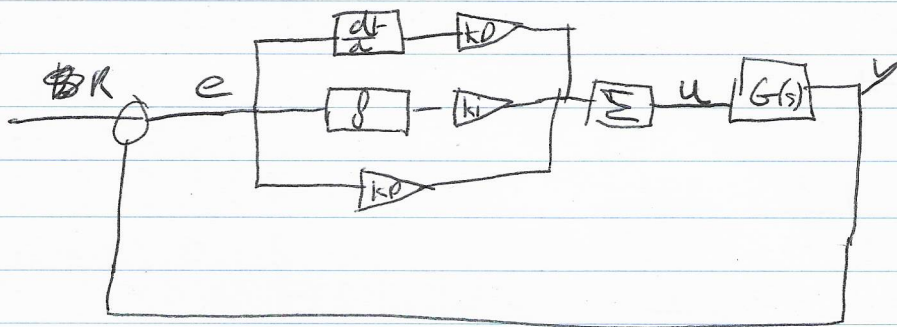
43/50

Yang

1. ~~A PID Controller must~~

A controller measures an output and compares it with a set point. ~~PID Controller~~ This value produced by measuring input compared with the set point is the error.

PID controller then use 3 terms; Proportional, integral & derivative. The proportional control measures the ~~error~~ and ~~no~~ current error and multiplies it by a gain k_p . The integral term takes into account all previous errors and multiplies that by the gain k_i . The derivative term ~~compensates for~~ ~~future~~ monitors the rate of change of the error and multiplies it by the gain k_d . These three values are then summed before being input into the plant as shown below.



The benefits of a PID Controller is that they are very sophisticated and with correct tuning can produce quick changes in process output with minimal overshoot. ①

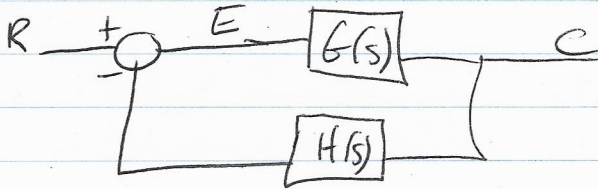
An example use case would be controlling pH using ~~CO₂~~ of water using CO₂. ①

Two state control only has two states on & off they are a lot ~~rather~~ more simple than PID controllers & require no tuning without hysteresis they will constantly switch on and off around the set point. ③

An example would be a central heating system. A temperature is set, if the measured input is less than the system turns on until the set point is reached and then turns off. ⑦

⑥ 6

2



$$G(s) = \frac{k}{1+Ts} \quad H(s) = \frac{1}{ts} \quad k=1.7$$

$$T=0.2$$

$$t=0.5$$

$$G(s) = \frac{1.7}{1+0.2s} \quad H(s) = \frac{1}{0.5s}$$

$$Tf = \frac{G}{1+GH}$$

$$Tf = \frac{1.7}{1+0.2s} \div \left(1 + \frac{1.7}{1+0.2s} \times \frac{1}{0.5s} \right)$$

$$Tf = \frac{1.7}{1+0.2s} \div \left(1 + \frac{1.7}{0.5s + 0.1s^2} \right)$$

$$Tf = \frac{1.7}{1+0.2s} \div \frac{0.1s^2 + 0.5s + 1.7}{0.1s^2 + 0.5s}$$

$$Tf = \frac{(1.7)(0.1s^2 + 0.5s)}{(1+0.2s)(0.1s^2 + 0.5s + 1.7)}$$

$$Tf = \frac{0.17s^2 + 0.85s}{0.1s^2 + 0.5s + 1.7 + 0.02s^3 + 0.1s^2 + 0.34s}$$

$$2 \quad T_f = \frac{0.17s^2 + 0.85s}{0.02s^3 + 0.2s^2 + 0.84s + 1.7}$$

(3)

Zeros

$$0.17s^2 + 0.85s = 0$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad A = 0.17 \quad b = 0.85 \quad C = 0$$

$$\frac{-0.85 \pm \sqrt{0.85^2 - 0}}{2 \times 0.17}$$

$$\frac{-0.85 \pm 0.85}{0.34}$$

$$\text{Zeros} = 0, -5$$

(3)

Poles

$$0.02s^3 + 0.2s^2 + 0.84s + 1.7$$

$$(0.02)(s^3 + 10s^2 + 42s + 85)$$

$$(0.02)(As+B)(Cs^2+Ds+E)$$

$$A \times C = 1 \quad A = 1$$

$$(A \times D) + (B \times C) = 10 \quad C = 1$$

$$(B \times D) + (A \times E) = 42 \quad B = 5$$

$$(B \times E) = 85 \quad D = 5$$

$$E = 17$$

$$17 \times 5$$

$$1 \times 85$$

$$(0.02)(s+5)(s^2+5s+17)$$

$$s+5=0$$

$$s = -5$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \quad a=1 \quad b=5 \quad c=17$$

$$\frac{-5 \pm \sqrt{5^2 - 4 \times 1 \times 17}}{2}$$

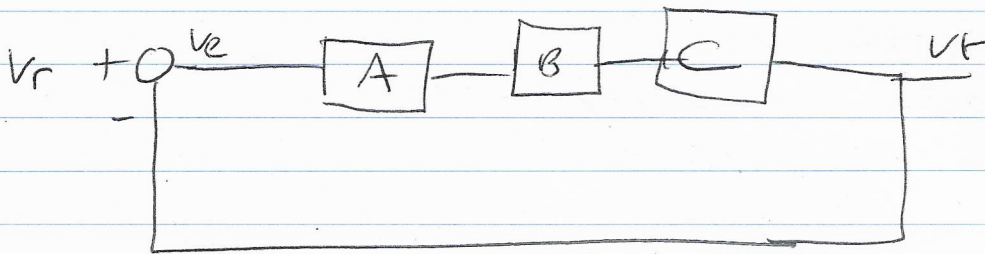
$$\frac{-5 \pm \sqrt{25 - 68}}{2}$$

$$\frac{-5 \pm j\sqrt{43}}{2}$$

$$s = -2.5 \pm j21.5 \times -2.5 \pm j3.2787$$

see graph 3 continued after Q5

3



$$A = \frac{1}{s+1} \quad B = \frac{2.1}{3.1s+1} \quad C = \frac{1}{2s+1}$$

$$R_1 = \frac{1}{\sqrt{\omega^2+1}} \quad R_2 = \frac{2.1}{\sqrt{3.1^2\omega^2+1}} \quad R_3 = \frac{1}{\sqrt{2^2\omega^2+1}} \quad R_T = R_1 \times R_2 \times R_3$$

$$\theta_1 = \tan^{-1}(\omega) \quad \theta_2 = \tan^{-1}(3.1\omega) \quad \theta_3 = \tan^{-1}(2\omega) \quad \theta_T = -\theta_1 - \theta_2 - \theta_3$$

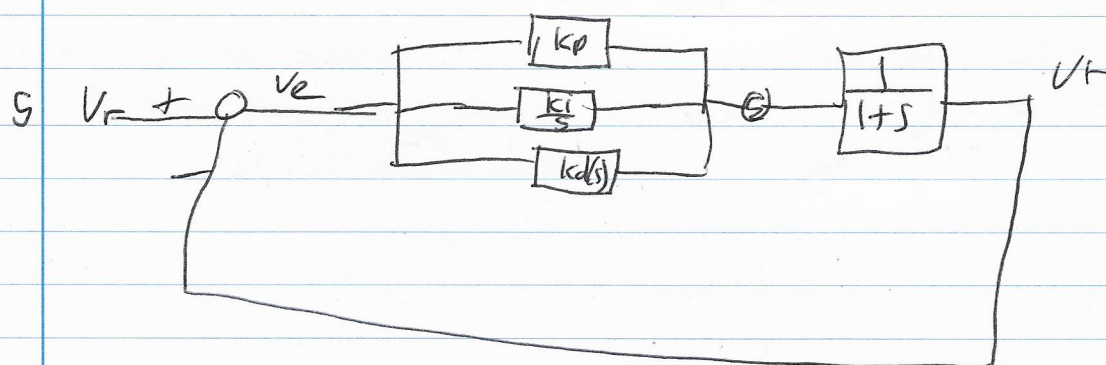
ω	R_1	R_2	R_3	R_T	θ_1	θ_2	θ_3	θ_T
0.5	0.894	1.138	~~0.447~~ 0.707	0.714	26.6	57.2	45	-128.8
1	0.707	0.645	0.447	0.204	45	72.1	63.4	-180.5
1.5	0.555	0.442	0.316	0.078	56.31	77.9	71.6	-205.81
2	0.447	0.334	0.243	0.036	63.4	80.8	76.0	-220.2
2.5	0.371	0.269	0.196	0.0195	68.2	82.6	78.7	-224.5
3	0.316	0.225	~~0.164~~ 0.164	0.0116	71.6	83.49	80.5	-236.0
3.5	0.275	0.193	0.141	7.48×10^{-3}	74.1	84.7	81.9	-240.7
4	0.243	0.168	0.124	5.06×10^{-3}	75.9	85.4	82.9	-244.2

See graph 1 + graph 2

graph -

- 4 Sensitivity ✓
 Accuracy ✓
 Range of operation ✓
 Cost ✓

- Sensitivity would be greater in the chlorine ^{plant} factory than a home due to the dangers of excess chlorine in drinking water ✓
- Accuracy would also be greater in chlorination plant for the same reasons as above. ✓
- Range of much larger volumes of chlorine would be inputted into a chlorination process. ✓
- Cost would be as cheap as possible for better as long as the reach required Spec. ✓



$$G = \left(1 + \frac{1}{s} + 1s\right) \times \frac{1}{1+s} = \frac{s+1+s^2}{s+s^2} \quad \text{✓}$$

$H = 1$ because no feedback sensor

$$T_f = \frac{1 + \frac{1}{s} + 1s}{1 + \frac{1 + \frac{1}{s} + 1s}{1+s}} \quad T_f = \frac{s+1+s^2}{s+s^2}$$

$$= \frac{s+1+s^2}{1+s} \quad T_f = \frac{s+1+s^2}{s+s^2}$$

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

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

$$5 \quad T_f = \frac{(s+1+s^2)(s^2+s)}{(2s^2+2s+1)(s^2+s)}$$

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

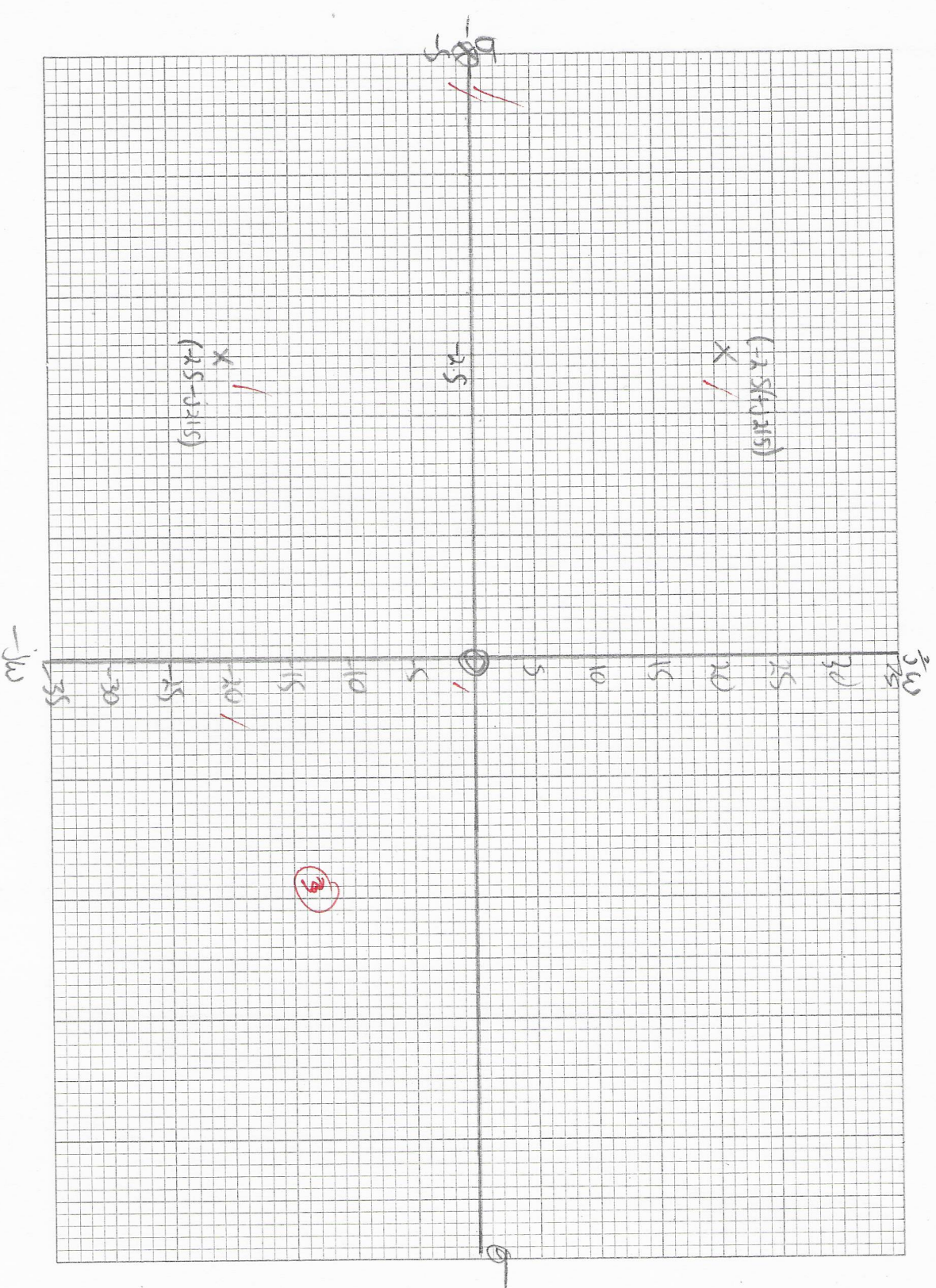
$$T_f = \frac{s^4 + 2s^3 + 2s^2 + s}{2s^4 + 4s^3 + 3s^2 + s}$$

5.

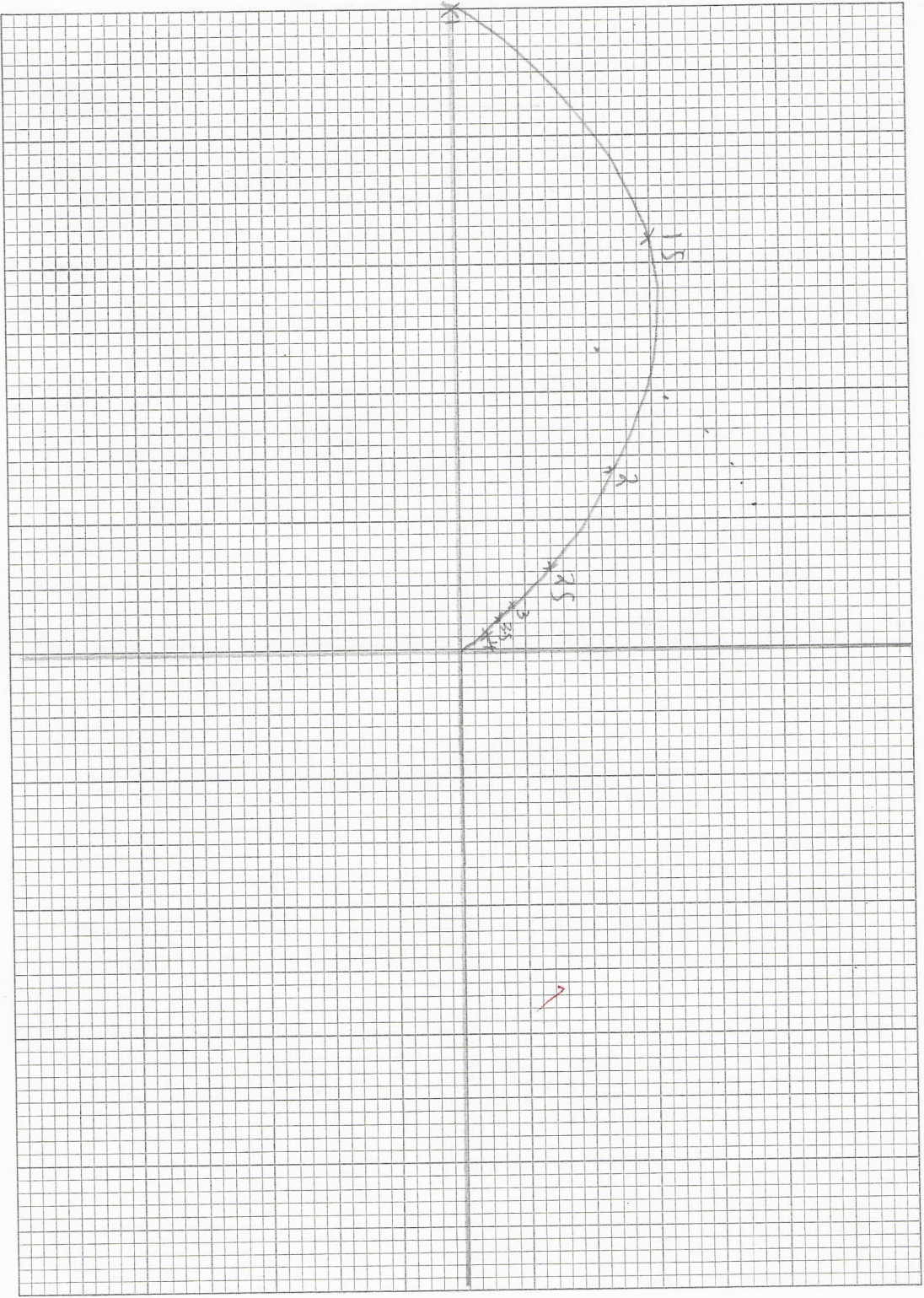
2 cont See graph 3

All poles are on the left hand side so the system is considered to be stable. The pole at $-5, 0$ will produce an exponential decay at $A = A_0 e^{\sigma t}$. And the complex conjugate pair will produce an oscillating decay given by $A = A_0 e^{\sigma t} \sin(\omega t + \phi)$.

P143797 Graph 3-Liam Thomas



90



270

P143797 Graph 1

