

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:

Miller

FORENAME(S):

Phyllis, Colima

1	Student Number	P140808
2	Title of Examination Paper	Instrumentation & Control
3	Module Code	M7X01643
4	Date and Time of Examination	18/05/18 3pm
5	Examination Venue	
6	Seat Number	
7	Number of Answer Books handed in	1

[illegible]

67.1%

34.5/50

Gay

Q. 1

A two state controller is a controller which has two active states of operation, most commonly referred to as an on state and an off state.

An example of a two state controller is a central heating system for a home where a thermostat controls the temperature of the building. A system like this often uses hysteresis to ensure that the system does not turn on and off repeatedly. These systems are often inaccurate as this example relies on hysteresis to function and can easily be affected by outside errors that aren't accounted for such as amount of insulation in building walls.

A PID Controller is a controller which uses K_p , K_i and K_d gains to control the output and adjust the output depending on the error signal. To do this, the controller will look at the feedback error signal and identify the difference in terms of scale and rate of change from the desired output and make adjustments accordingly.

K_p , or Proportional, ~~refers to~~ takes into account the present value of the error signal and is ^{then} applied to the main output signal.

K_i , or Integral, takes into account the ^{accumulation of previous values} ~~present and previous values~~ of the error signal and is ^{then} applied to the main output signal.

K_d , or Derivative, takes into account possible future error signals by looking at the rate of change in previous error signals, and is then applied to the main output signal.

An example of a PID system is a remote-operated pillar drill which can be moved across two horizontal axis as well as lowered and raised. The PID system would take into account the current error from the set position, the accumulation of previous errors from previous set positions, and the rate of change of which the drill is making at to different positions. All of these would help ensure that the drill remains accurate by swiftly ~~over~~ correcting itself.

However, a system like this can become vulnerable to hysteresis as while it will correct for any errors, there could be a significant delay between inputs and as a result may oscillate to the point of becoming unstable until all input is ceased.

(6)

Q.2.

$$G_{cs} = \frac{k}{1 + \tau s}$$

$$H_{cs} = \frac{1}{t s}$$

$$k = 1.7$$

$$\tau = 0.2$$

$$t = 0.5$$

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

$$G_{cs} = \frac{1.7}{1 + 0.2s}$$

$$H_{cs} = \frac{1}{0.5s}$$

$$\frac{\frac{1.7}{1 + 0.2s}}{1 + \left(\frac{1.7}{1 + 0.2s}\right)\left(\frac{1}{0.5s}\right)}$$

Expand
Brackets...

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

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

Multiply top numerator
by bottom denominator

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

$$\frac{0.5s + 0.1s^2 + 1.7}{0.5s + 0.1s^2 + 1.7}$$

$$\frac{0.85s + 0.17s^2}{1 + 0.2s}$$

$$0.5s + 0.1s^2 + 1.7$$

~~Multip~~

$$\frac{0.85s + 0.17s^2}{(1 + 0.2s)(0.5s + 0.1s^2 + 1.7)}$$

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

$$\frac{0.85s + 0.17s^2}{0.02s^3 + 0.2s^2 + 0.84s + 1.7} = \text{T.F.} \quad (3)$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Zeros - two

$$a = 0.17$$

$$b = 0.85$$

$$c = 0$$

$$\frac{-0.85 \pm \sqrt{0.85^2 - (4 \times 0.17 \times 0)}}{2 \times 0.17}$$

$$\frac{-0.85 \pm \sqrt{0.85^2}}{0.34}$$

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

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

$$-2.5 \pm 2.5 \quad \times \quad \text{Complex pair.} \quad (2)$$

Poles - three

$$0.02s^3 + 0.2s^2 + 0.84s + 1.7 \quad \checkmark$$

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

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

$$\begin{aligned} A &= 1 \\ B &= 5 \\ C &= 1 \\ D &= 5 \\ E &= 17 \end{aligned}$$

$$\begin{aligned} s^3 &= 1 \\ s^2 &= 5 \\ s^1 &= 24 \\ s^0 &= 42.5 \end{aligned}$$

$$\begin{aligned} a &= A \times C \\ b &= B \times C + A \times D \\ c &= B \times E + A \times D \\ d &= B \times E \end{aligned}$$

$$0.02(s + 5)(s^2 + 5s + 17) \quad \checkmark \quad (2)$$

First pole

$$s = -5 \quad \checkmark$$

Second & third poles

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\begin{aligned} a &= 1 \\ b &= 5 \\ c &= 17 \end{aligned}$$

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

$$\frac{-5 \pm \sqrt{5^2 - 68}}{2} \quad \checkmark$$

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

$$j = \sqrt{-1}$$

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

$$\frac{-5}{2} \pm \frac{j6.557}{2}$$

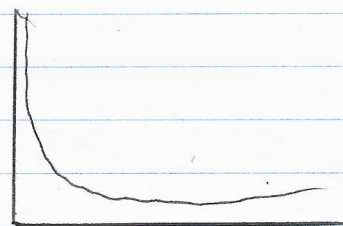
$$-2.5 \pm j3.278$$

Complex pair (3)

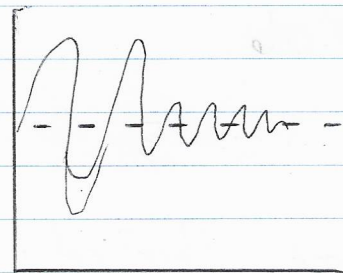
the zeros do not affect system stability and are negligible

the first pole (single) shows a damping factor while the complex pair shows dampening combined with oscillation. This means the output signal will decrease and lose oscillation

because all the poles are on the left real side, the system is stable as all errors will dampen.



Graph (separate sheet) - (3)





$$\frac{A}{B+C}$$

0.3

$$0.5 < \omega < 4$$

$$R = \frac{A}{\sqrt{B^2 + C^2}}$$

$$R_1 = \frac{1}{\sqrt{\omega^2 + 1}}$$

$$\theta = \tan^{-1} \frac{B}{C}$$

$$R_2 = \frac{2.1}{\sqrt{3.1^2 \omega^2 + 1}}$$

$$R_3 = \frac{1}{\sqrt{2^2 \omega^2 + 1}}$$

$$R_t = R_1 + R_2 + R_3$$

$$\theta_1 = \tan^{-1}(C\omega)$$

$$\theta_2 = \tan^{-1}(3.1\omega)$$

$$\theta_3 = \tan^{-1}(2\omega)$$

$$\theta_t = -\theta_1 - \theta_2 - \theta_3$$

R_tθ_t~~θ_t~~

1.9171	-138.966	~~-85.836~~
0.8979	-205.017	
0.5004	-227.32	
0.312	-238.366	
0.2106	-244.953	
0.151	-249.31	
0.113	-252.397	
0.0876	-254.694	

ω	R ₁	R ₂	~~R₃~~	R ₃	R _t	θ ₁	θ ₂	θ ₃
0.5	0.8	0.6171		0.5	0.2408	26.565	67.401	45
1	0.5	0.1979		0.2	0.097	45	84.054	75.963
1.5	0.3076	0.0928		0.1	0.00285	56.309	87.352	83.659
2	0.2	0.0532		0.0588	0.000625	63.434	88.509	86.423
2.5	0.1379	0.0343		0.0384	0.000181	68.198	89.046	87.709
3	0.1	0.0240		0.027	0.0000648	71.565	89.337	88.408
3.5	0.0754	0.0176		0.02	0.0000265	74.054	89.513	88.830
4	0.0588	0.0135		0.0153	0.0000121	75.963	89.627	89.104

Nyquist Plot - Separate Sheet

(3)



Question No.

Examiner Only

~~Q1~~

Arholwr yn unig

ff y Cwestiwn

Q.4

Sensor Specifications

- **Range** / - the range which the sensor must operate across
- **Sensitivity** / - the precision of the value read and the actual value.
- **Accuracy** / - the difference between the value read and the actual value
- **Compatibility** / - whether the sensor can detect the subject or operate in the environment.
- **Linearity** / - the output curve of the sensor and if it is constant across the whole range.
- **Hysteresis** / - the lag time between the initial time the value appears and when it is registered.
- **Response time** / - the time taken to read and store data.
- **Cost** / - overall cost of the sensor.

For chlorination control, a sensor which can measure chlorine over a small range with high sensitivity and accuracy is needed. It must produce a linear output curve and have no hysteresis in order to obtain a real-time reading and to avoid delay in emergencies. The overall cost can be expected to be very high.

For gas detection, a sensor which can measure the gas used over a large range with low sensitivity and accuracy is needed. The linearity should preferably be consistent but the response time and hysteresis is negligible as it is only data logging and is not heavily relied upon. The overall cost can be expected to be low.

5

Q. 5

$$\frac{G}{HGH}$$

$$G = (K_p + \frac{K_i}{s} + K_d s) \left(\frac{1}{1+s} \right) \checkmark$$

$$G \left(1 + \frac{1}{s} + 1s \right) \left(\frac{1}{1+s} \right) \checkmark$$

(2)

$$\frac{(1 + \frac{1}{s} + 1s)}{1 + (1 + \frac{1}{s} + 1s) \left(\frac{1}{1+s} \right)} \times$$

$$\frac{(1 + \frac{1}{s} + 1s)}{1 + \cancel{\frac{1}{1+s}} + \frac{1}{2s} + \frac{1s}{1+s}}$$

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

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

$$\frac{(1 + \frac{1}{s} + 1s)}{\frac{s^2 + 4s + 3}{s^2 + 3s + 1}}$$

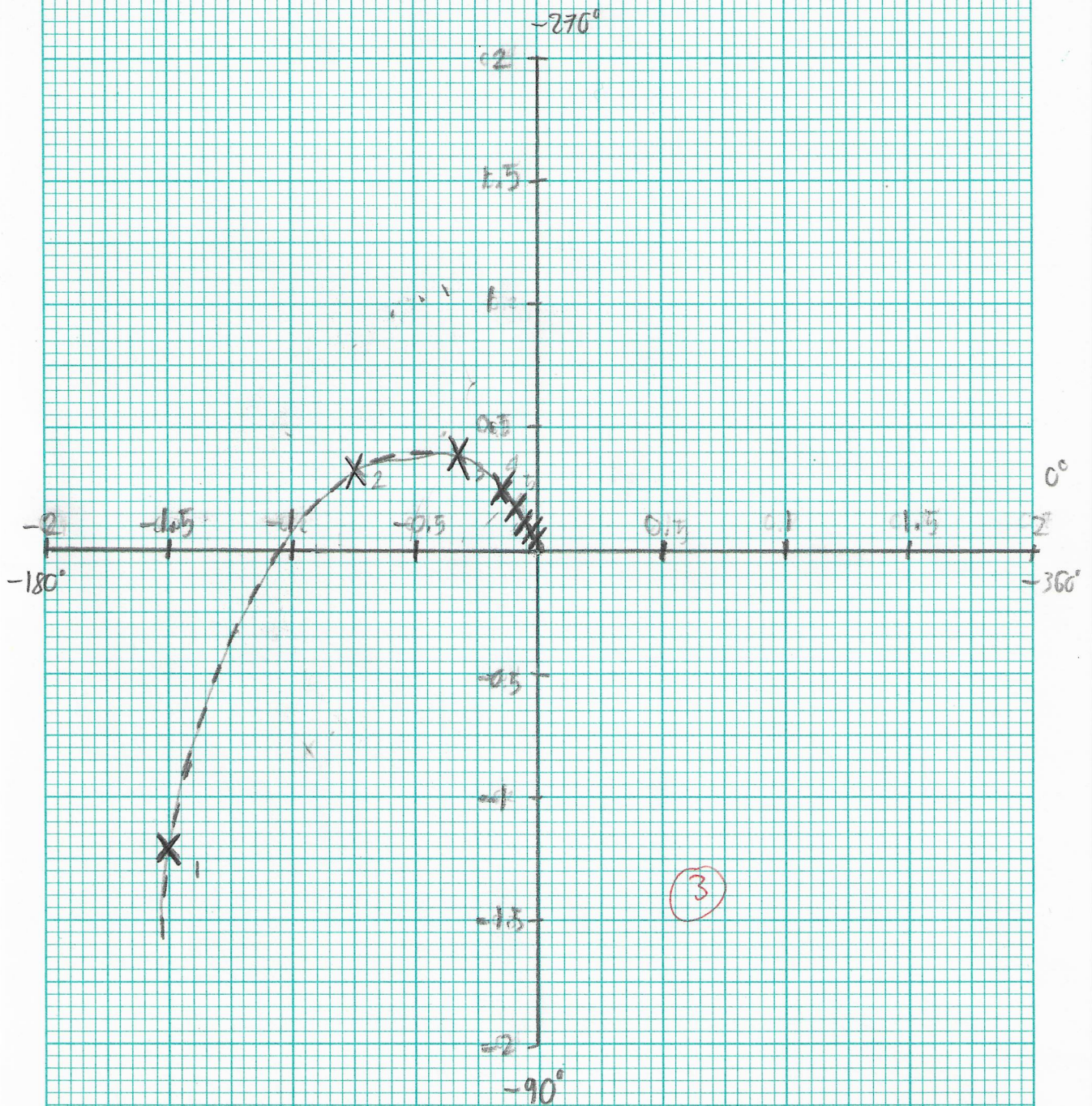
$$\frac{(s^2 + 3s + 1)(1 + \frac{1}{s} + 1s)}{\cancel{s^2 + 4s + 3}}$$

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

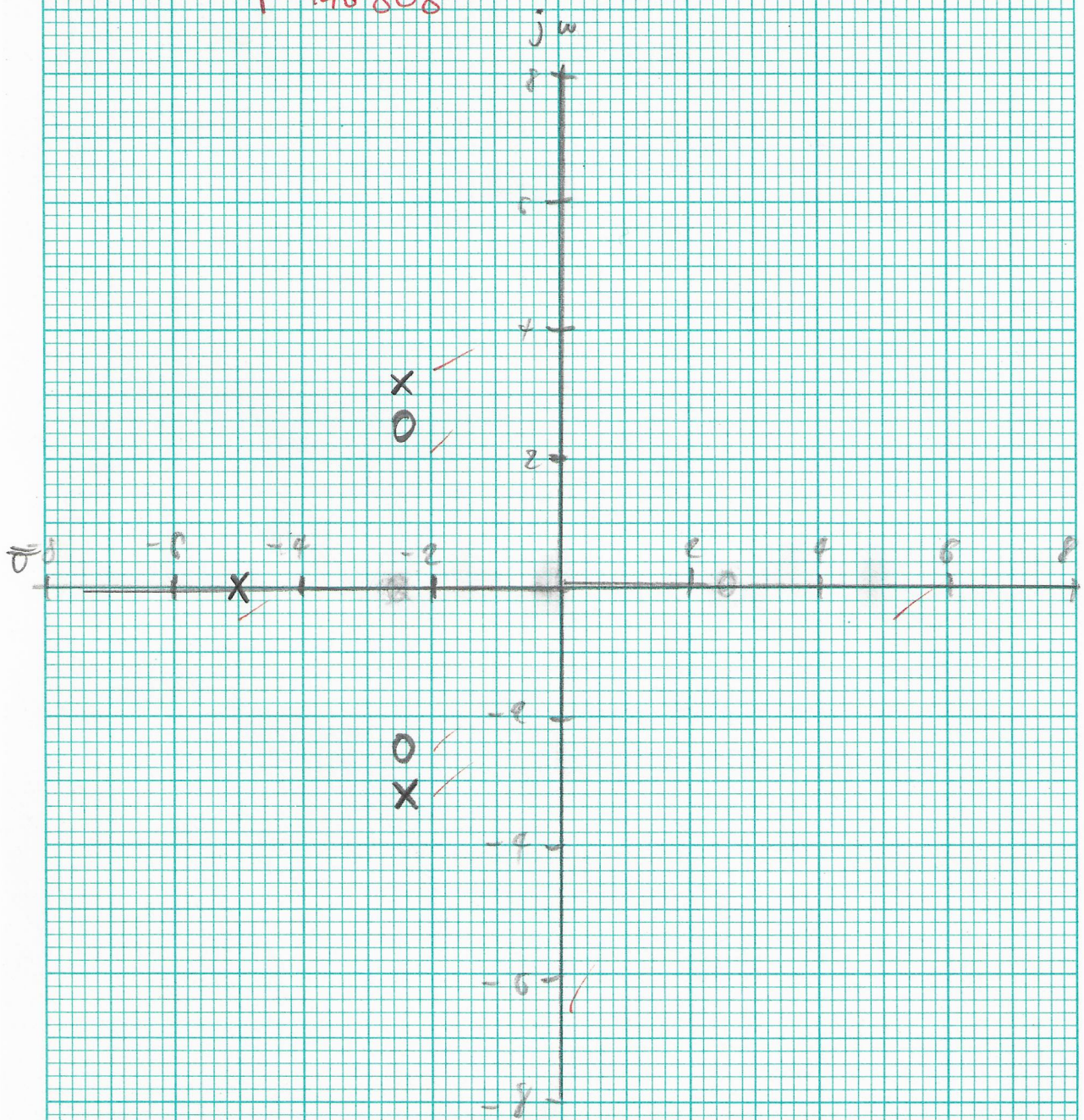
$$\frac{s^3 + 4s^2 + 4s + 1 + \frac{s^2}{s} + \frac{3s^2}{s} + \frac{1}{s}}{s^2 + 4s + 3} = \underline{\underline{T.F}}$$

P148808

Q.3 Nyquist Plot



P 140808



Q. 3/2 Pole Zero Plot (3)