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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.
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	P139577
2	Title of Examination Paper	Instrumentation and Control
3	Module Code	M7X01643
4	Date and Time of Examination	15:00 18/05/2018
5	Examination Venue	Gym
6	Seat Number	G081
7	Number of Answer Books handed in	1

List the numbers of the questions you have attempted	Office Use
1	6
2	7
3	13½
4	5
5	2
Total	33½ / 80

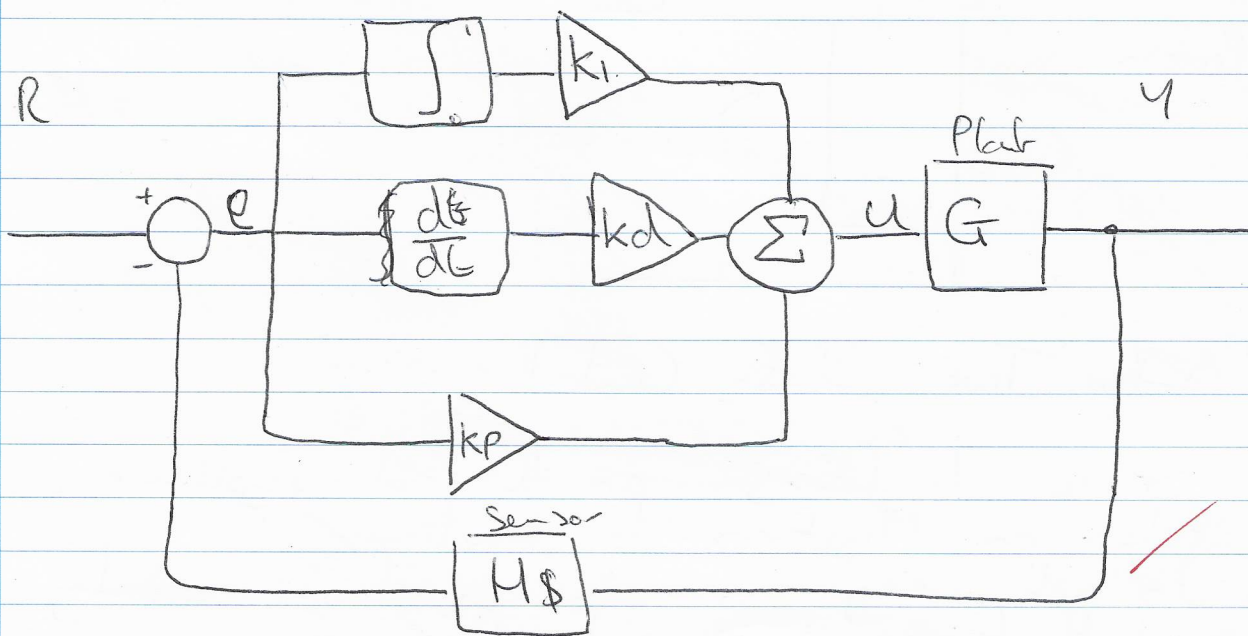
(Gweler yr ochr arall am y fersiwn Cymraeg)

67%

33.5/50

Garik

① PID Controller



$$\frac{u}{e} = \left(\frac{k_i}{s} + k_d s + k_p \right)$$

$$\frac{Y}{R} = \frac{\left(\frac{k_i}{s} + k_d s + k_p \right) \cdot G}{1 + \left(\frac{k_i}{s} + k_d s + k_p \right) \cdot G \cdot M}$$

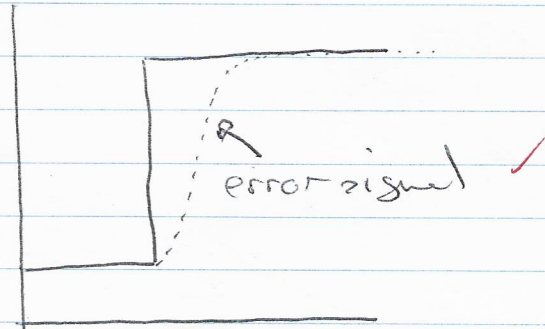
$$1 + \left(\frac{k_i}{s} + k_d s + k_p \right) \cdot G \cdot M$$

- * PID Controller takes into account the rate of change in the error.
- * The error signal is multiplied by the derivative function $\frac{d}{dt}$ and the constant k_d to give a signal that is sent to the summing operator Σ . This is the rate of change in error.
- * The error signal is also passed through an integral set of measurements to ensure the error is between these points.
- * Error is multiplied by k_p constant before it is sent to the summing operator Σ .
- * Offers a control signal that is sent to the plant or process.

Process
G

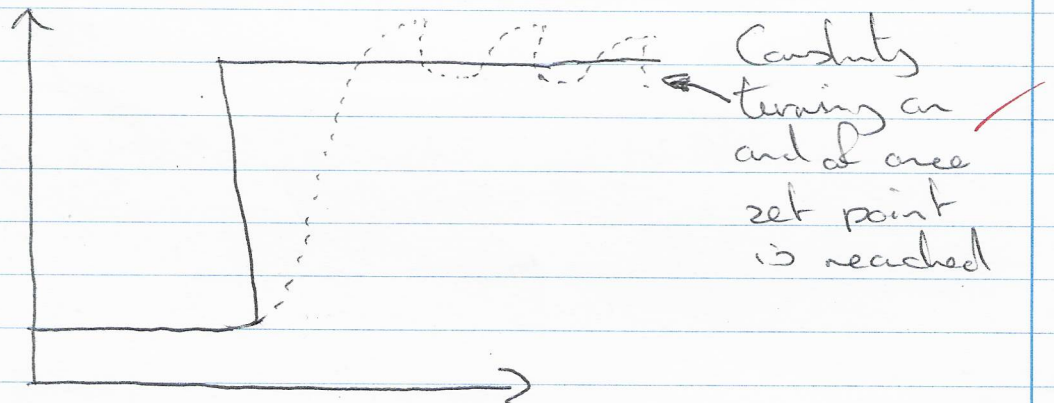
① PID

Process output



Two State Controller

- * Simple to Design as it ~~cost~~ system ✓
relies on hysteresis to function ✓
- * Is not very accurate as it is ~~constantly~~ constantly turning on and off. ✓
- * Has a relatively cheap overall cost. ✓
- * Should be applied to simple systems such as Central Heating ✓



⑥ ✓

$$(2) \quad \frac{G_k}{1+T_g} = \frac{1.7}{1+0.2\$}$$

$$M\$ = \frac{1}{t\$} = \frac{1}{0.5\$}$$

$$\frac{G}{1+GM} \therefore TF = \frac{1.7}{1+0.2\$}$$

$$1 + \frac{1.7}{1+0.2\$} \cdot \frac{1}{0.5\$}$$

$$= \frac{1.7}{1+0.2\$}$$

$$1 + 0.5\$ + 0.1\$^2$$

$$= \frac{1.7}{1+0.2\$}$$

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

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

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

$$\text{Zeros} = \frac{0.17\$^2}{a} + \frac{0.85\$}{b} = 0$$

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

$$0.85,$$

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

$$\text{Zeros} = \underset{a}{0.17}s^2 + \underset{b}{0.85}s + \underset{c}{0} = 0$$

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

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

$$= \frac{-0.85 \pm \sqrt{0.85^2}}{2 \cdot 0.17}$$

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

$$\boxed{\text{Zeros} = 0 \text{ and } -5.}$$

③

$$\text{Poles} = 0.02s^3 + 0.2s^2 + 0.84s + 1.7$$

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

Divide by 0.02

$$s^3 + 10s^2 + 42s + 85$$

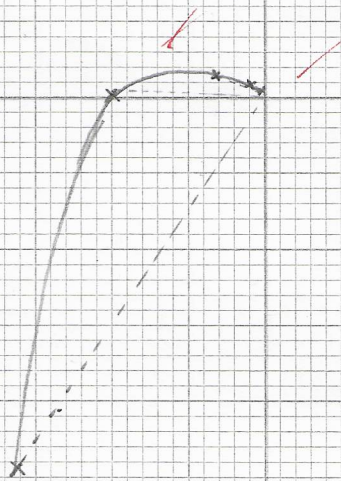
$$(As + B)(Cs^2 + Ds + E) \cdot 0.02 = 0.02 \quad \therefore \hat{A}, \hat{C} = 1, 1, 2,$$

Question ③

-180
180

-90 270

0



2 1/2

-270
90

$$\textcircled{3} \quad R_1 = \frac{1}{s+1} = \frac{1}{\sqrt{\omega^2+1}} \quad \checkmark$$

$$R_2 = \frac{2 \cdot 1}{3 \cdot 1s + 1} = \frac{2 \cdot 1}{\sqrt{3 \cdot 1^2 \cdot \omega^2 + 1}} \quad \checkmark$$

$$R_3 = \frac{1}{2s+1} = \frac{\cancel{\theta} 1}{\sqrt{2^2 \cdot \omega^2 + 1}} \quad \checkmark$$

$$R_{\text{total}} = R_1 \times R_2 \times R_3 \quad \checkmark$$

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

$$\theta_2 = \tan^{-1}(3 \cdot 1^2 \cdot \omega^2) \quad \checkmark$$

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

$$-\theta_1 - \theta_2 - \theta_3 = \theta_{\text{tot}} \quad \checkmark$$

3

③

ω	R_1	R_2	R_3	R_{tot}	θ_1	θ_2	θ_3	θ_{tot}
0.5	0.8944	1.138	-0.5773	-0.5876	26.565	57.172	45	-128.737
1.0	0.7071	0.6447	+0.4472	+0.204	45	72.121	63.435	-180.556
1.5	0.5547	0.4415	+0.3162	+0.0774	56.309	77.863	71.565	-208.737
2.0	0.4472	0.3344	+0.2425	+0.0363	63.434	80.837	75.964	-220.235
2.5	0.3713	0.2687	+0.1961	+0.01956	68.198	82.647	78.69	-229.535
3.0	0.3162	0.2245	+0.1644	+0.1167	71.565	83.863	80.538	-235.966
3.5	0.2747	0.1927	+0.1414	+0.00748	74.054	84.774	81.869	-240.657
4.0	0.2425	0.1689	+0.1240	+0.00507	75.964	85.389	82.875	-244.28

⑧

Graph on separate paper

- 2 1/2

④ a) Range - is the operating range suitable for the dosing rate, Generally ~~pH sensors~~ ^{relatives} flow sensors with large ranges have low accuracy and sensors with small ranges have high accuracy ✓

a) would require large range as a large volume per second is anticipated ✓

b) would require a smaller range as it is for a domestic use. ✓

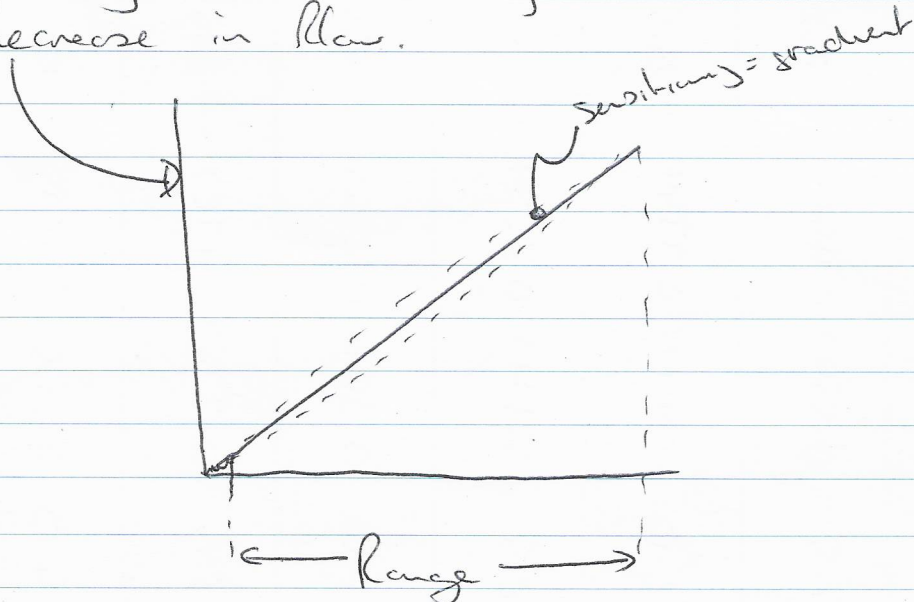
Sensitivity ✓ - If the error signal is increased and decreased rapidly the meter should react ~~with~~ in a short enough time to correct the error

a) would require high sensitivity as the dosing of chlorine is highly controlled

b) would ~~not~~ require a low sensitivity as the system is dependent on output.

The Physical environment ✓ - is the Environment suitable for the sensors, i.e. temp, pressure, pH,

Linearity ✓ - Ideally a flow meter should be perfectly linear during increase in flow and decrease in flow.



④ Response time - How long does it ~~take~~
 How long it takes to respond to an error signal
 this results in the ~~adjusted~~ adjustment
 adjustment of the plant it is controlling ✓

Cost - ~~as~~ the meter should be
 as cheap as possible for the use
 a. would require a high cost meter as the
 range ~~and area~~ is relatively large and the
 conditions are hazardous
 b. would be medium cost as it has to
 be quite accurate and used in a high pressure
 environment. ✓

⑤ ✓

⑤

$$\left(k_p + \frac{k_i}{s} + k_d s\right)$$

$$H_d = 1$$

$$k_p = 1 \quad k_i = 1 \quad k_d = 1$$

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

$$\left(k_p + \frac{k_i}{s} + k_d s\right) \cdot \frac{1}{1+s}$$

$$1 + \left(k_p + \frac{k_i}{s} + k_d s\right) \cdot \frac{1}{1+s} \cdot 1s$$

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

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

$$\left(s + s + s^2\right) \cdot \frac{1}{1+s}$$

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

$$\left(s + s + s^2\right) \cdot \frac{1+1+s}{1+s}$$

$$1 + (s + s + s^2) \cdot 1 + s \cdot 1s + 1$$

②



$$\frac{dI}{dt} = \left(R_1 I + \frac{R_2}{I} + k_d I^2 \right) \\ \left(I + I + I^2 \right)$$