

Control + Automation ExamLewis Christopher
1909572Question 1

a) A measurement is deemed as a single shot value quantity taken by the transducer, while short-term continuous readings are referred to as monitoring.

b) The two types of error in a control system are either dynamic or static. Dynamic errors are errors which occur during the working of the device, such as hysteresis, response time or settling time. Static errors are machine related faults such as non-linearity or drift.

c) The change in the length of the gauge wire will cause a proportional change in the device resistance.

ii) overall sensitivity

$$K_T = K_1 \cdot K_2 \cdot K_3 \cdot K_4$$

$$K_T = (0.75)(150 \times 10^{-3})(500)(1) \\ = 56 \text{ cm/rad.}$$

$$\frac{\Delta}{\text{rad}} \quad \frac{\Delta}{\Delta} \quad \frac{\Delta}{\text{cm}} \frac{\Delta}{\Delta}$$

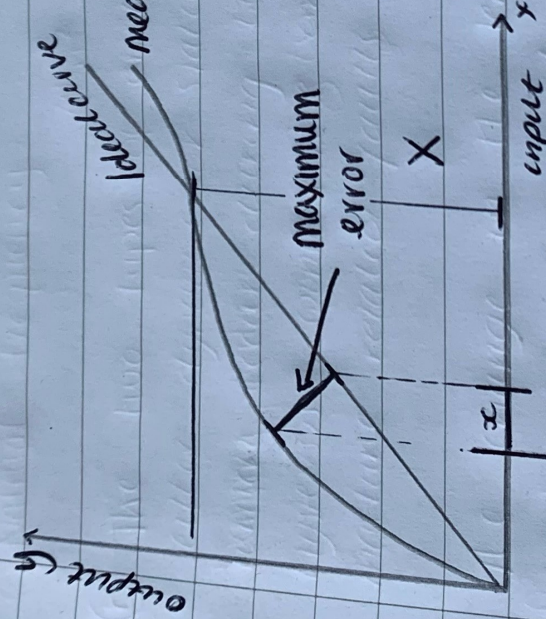
ii) $56 = \frac{\text{cm}}{\text{rad}} \Rightarrow \text{rad} = \frac{8.5}{56}$

$\therefore \Rightarrow \text{angular displacement} = 0.15 \text{ rad}$

iii) The wheatstone bridge is used to determine the value of an unknown resistance, by changing it into a voltage value to be read by the recorder.

Question 1

- © Non-linearity is the maximum error for either an input or output when an output curve is produced and is given as a percentage of its full range.



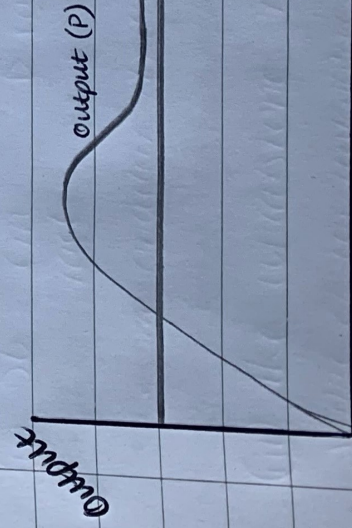
from diagram calculated
as $(x/X) \times 100$
to give as percentage
of full range.

Question 2.

- a) An open loop control system has no error signal to account for differences between desired and actual outputs. Closed systems have a feedback loop and comparison element to correct for any disturbances.

Open loop provides good reliability due to simplicity but lack of automatic correction makes it highly inaccurate, with a lot of cycling around a set point. There is more complexity in a closed loop system meaning less reliable but it is a lot better and more accurate at achieving a steady state setpoint due to the inclusion of the comparison element.

- b) Proportional control is an example of a continuous control strategy, providing uninterrupted inputs and outputs to the system. Proportional control produces a control action, proportional to the error signal. For example the size of the error will dictate the output signal to the actuator. The equation for proportional control is given as $K_p \cdot e(t)$. As the diagram shows, there is still an overshoot causing steady state error but not as



error but not as

badly.

Setpoint

Combine with

Integral + derivative

for higher

accuracy.

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$$G = \frac{O_o}{E} \Rightarrow E = \frac{O_o}{G} \quad \text{and} \quad H = \frac{F}{O_o} \Rightarrow F = H O_o$$

$$E = O_i - F \quad (\text{Comparator})$$

Sub into comparator

$$O_o / G = O_i - H O_o$$

$$O_o = O_o / G + H O_o$$

Factorise for O_o

$$O_o = O_o \left(\frac{1 + G H}{G} \right)$$

$$\therefore \frac{O_o}{O_i} = \frac{G}{1 + G H} \quad \text{as required.}$$

$$\begin{aligned} \text{d) } \frac{O_o}{O_i} &= \frac{G}{1 + G H} = \frac{(5)(0.25)}{1 + (5)(0.25)(150 \times 10^{-3})} \quad \frac{\text{mA}}{\text{mA}} \quad \frac{\text{mV}}{\text{mA}} \\ &= 1.053 \quad \text{V/V} \end{aligned}$$

© • Automatic level of a cooling tank.

- Automatic conveyor motor speed adjustment allowing for load disturbances.

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1909572Question 4

$$a) \quad 7.5 \frac{d^2 \theta_o}{dt^2} + 40 \frac{d\theta_o}{dt} + 300 \theta_o = 800 \theta_i$$

$$\frac{d^2 \theta_o}{dt^2} + \frac{40}{7.5} \frac{d\theta_o}{dt} + \frac{300}{7.5} \theta_o = \frac{800}{7.5} \theta_i$$

Natural frequency

$$\omega_n^2 = \frac{300}{7.5}$$

$$\omega_n = \sqrt{\frac{300}{7.5}} = 6.32 \text{ Hz}$$

$$\omega_n = 6.32 \text{ Hz}$$

Damping ratio

$$2 \zeta \omega_n = \frac{40}{7.5}$$

$$\zeta = \frac{5.3}{(2)(6.32)}$$

$\zeta = 0.422$, $\therefore$ the system is underdamped.

$$\begin{aligned}
 b) \quad \% \text{ Peak overshoot} &= \exp \left(\frac{-\zeta \pi}{\sqrt{1-\zeta^2}} \right) \times 100 \\
 &= \exp \left(\frac{-0.422 \pi}{\sqrt{1-(0.422^2)}} \right) \times 100 \\
 &= (0.232) \times 100 \\
 &= 23.2 \%
 \end{aligned}$$

Rise time

$$\begin{aligned}
 t_r &= \frac{\pi}{\omega_n} \\
 &= \frac{\pi}{(6.32)}
 \end{aligned}$$

Question 4.

$$\begin{aligned}\textcircled{b} \omega &= \omega_n \sqrt{1 - \zeta^2} \\ &= 6.32 \sqrt{1 - (0.422)^2} \\ &= 5.73 \text{ Hz}\end{aligned}$$

Rise time

$$t_r = \frac{\pi}{\omega} = \frac{\pi}{(2)(5.73)} = 0.27 \text{ s}$$

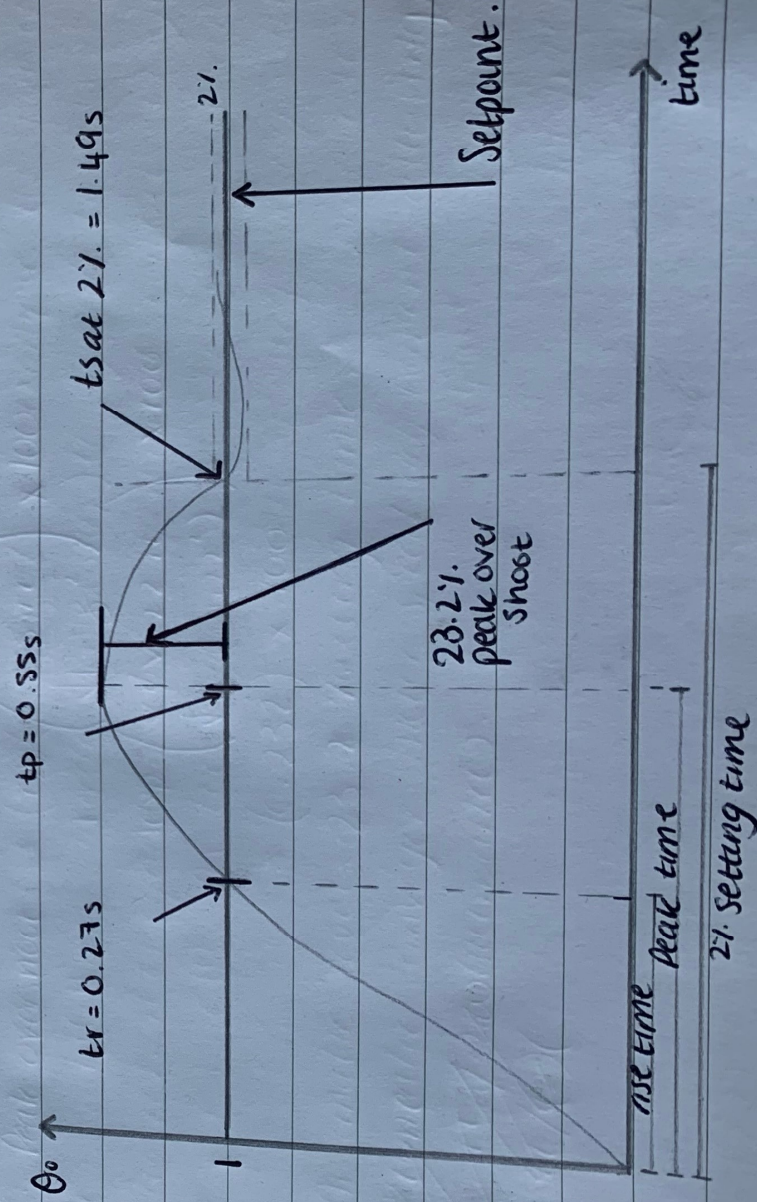
Peak time

$$t_p = \frac{\pi}{\omega} = \frac{\pi}{(5.73)} = 0.55 \text{ s}$$

2% Setting time

$$= \frac{4}{\zeta \omega_n} = \frac{4}{(0.422)(6.32)} = 1.499 \text{ s}$$

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19095372Question 4.

$$Q15 = e^{\left(\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}\right)} \times 100$$

$$\ln 0.15 = \frac{-\zeta\pi}{\sqrt{1-\zeta^2}}$$

$$-1.897(\sqrt{1-\zeta^2}) = -\zeta\pi$$

$$3.599(1-\zeta^2) = 9.87\zeta^2$$

$$3.599 = 13.469\zeta^2$$

$$\zeta = 0.517 \text{ for } 15\% \text{ overshoot}$$