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12/02/2021

Control & Automation Exam

ACMA6008

Question One

1)A) A measurement is a single act that quantifies an attribute of a part, equipment, service or process. Monitoring is to observe ('monitor') those measurements over time to detect trends. This can determine the performance of a machine (Example).

1)B) The first error typically found when taking a measurement is systematic error. These errors usually occur due to poor experimental design or methodology of the measurement system, meaning the reading can be biased.

The second error is random errors. These occur from unexpected causes and must be treated using statistical techniques. To determine the magnitude of random error, standard deviation about the mean value is specified.

1)C) Change in length of the gauge wire, causes proportional change in resistance of the strain gauge.

i) d) i) Sensitivity = $\frac{\text{Change in Output}}{\text{Change in Input}}$ $R \rightarrow \boxed{k} \rightarrow C$

$$\therefore \frac{C}{R} = k$$

$$k_1 = \text{Angular Potentiometer} = 0.75 \text{ } \Omega/\text{rad}$$

$$k_2 = \text{Wheatstone bridge} = 150 \text{ mV}/\Omega \approx 150 \times 10^{-3} \text{ V}/\Omega$$

$$k_3 = \text{Voltage amplifier (gain)} = 500 \text{ V/V}$$

$$k_4 = \text{Recording device} = 1.00 \text{ cm/V}$$

$$\therefore \frac{C}{R} = k_1 \times k_2 \times k_3 \times k_4$$

$$\frac{C}{R} = 0.75 \frac{\cancel{\Omega}}{\text{rad}} \times 150 \times 10^{-3} \frac{\cancel{\text{V}}}{\cancel{\Omega}} \times 500 \frac{\cancel{\text{V}}}{\cancel{\text{V}}} \times 1 \frac{\text{cm}}{\cancel{\text{V}}}$$

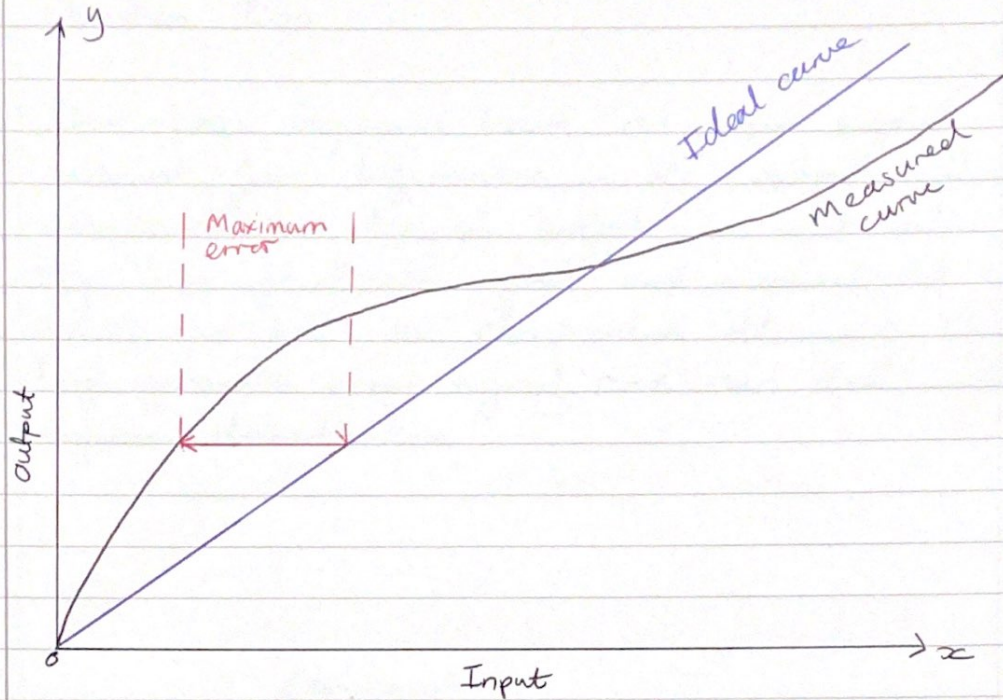
$$\frac{C}{R} = 56.25 \text{ cm/rad}$$

ii) $\frac{C}{R} = 56.25 \text{ cm/rad}$, where $C = 8.5 \text{ cm}$

$$\therefore C = 56.25 R, \quad R = \frac{C}{56.25} = \frac{8.5 \text{ cm}}{56.25 \text{ cm/rad}} = 0.151 \text{ rad}$$

iii) Changes resistance values into voltage to be ultimately read by the recorder.

1) E)



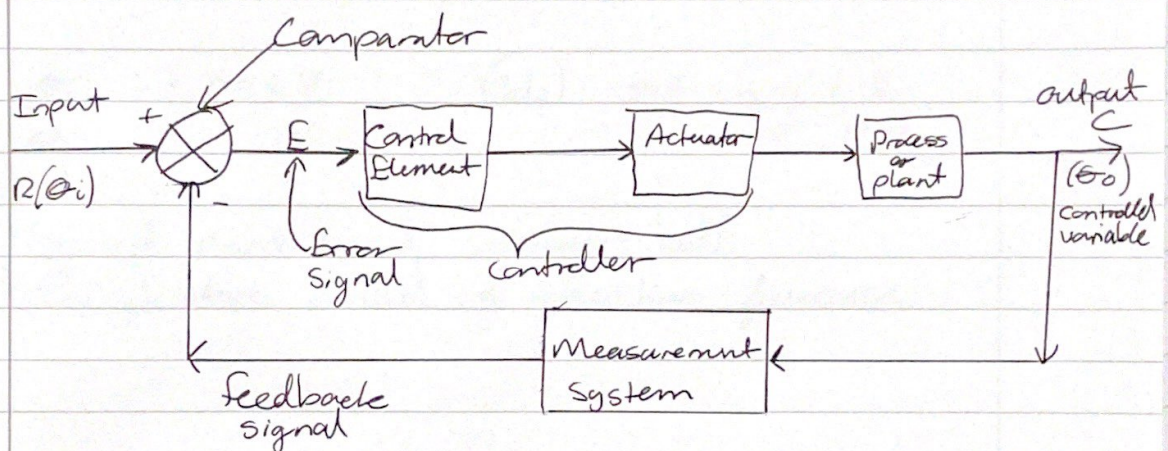
Non-linearity is the relationship of output/input being truly linear is rare. When the output curve produced, maximum error is determined for either input or output quantity. This is expressed as a percentage of full range for either input or output.

$$\therefore \frac{\Delta O_i}{O_i} \rightarrow \frac{\Delta O_o}{O_o} \therefore \Delta O_o \times \Delta O_i$$

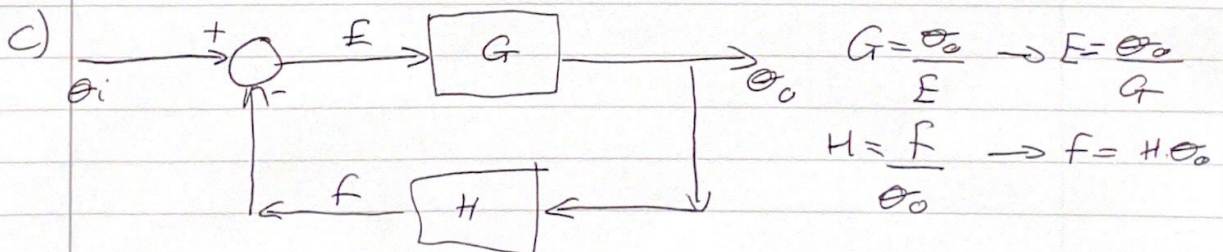
Question Two

- 2) A) Open-loop systems have no error signal to account for differences in the output value, compared to desired output, i.e. input value. Closed-loop has feedback signal and measurement system/device, as well as comparison element. Closed-loop generates error signal and can deal with system disturbances.

2) B)



Proportional control produces a control action that is proportional to the error signal.



Now, $E = \theta_i - f$

$$\therefore \frac{\theta_o}{G} = \theta_i - H \cdot \theta_o \rightarrow \frac{\theta_o}{G} + H \cdot \theta_o = \theta_i$$

2)c)
Continued

$$\text{So, } \theta_o \left(\frac{1 + G_2 H}{G_1} \right) = \theta_i$$

$$\text{Hence, } \frac{\theta_o}{\theta_i} = \frac{G_1}{1 + G_2 H}$$

2)d)

$$G_1 = 5.0 \text{ mA/V}$$

$$G_2 = 0.25 \text{ mm/mA}$$

$$H = 150 \text{ mV/mm} \approx 150 \times 10^{-3} \text{ V/mm}$$

$$\frac{\theta_o}{\theta_i} = \frac{G_1 G_2}{1 + (G_1 G_2 H)} = \frac{5 \times 0.25}{1 + (5 \times 0.25 \times 150 \times 10^{-3})}$$

$$\frac{\theta_o}{\theta_i} = 1.053 \frac{\text{V}}{\text{V}} \quad (3dp) \quad \frac{\text{mA} \times \text{mm} \times \text{V}}{\text{V} \times \text{mA} \times \text{mm}}$$

- e) • Speed control of conveyor belt
• Temperature control of induction furnace.

Question Four

$$4)A) \quad 7.5 \frac{d^2 \theta_0}{dt^2} + 40 \frac{d\theta_0}{dt} + 300 \theta_0 = 800 \theta_i$$

Convert system d.e into standard form.

$$\frac{d^2 \theta_0}{dt^2} + 2\zeta \omega_n \frac{d\theta_0}{dt} + \omega_n^2 \theta_0 = b_1 \omega_n^2 \theta_i$$

$$\therefore \frac{800}{7.5} = 106.6$$

$$\therefore 2\zeta \omega_n = \frac{40}{7.5} = 5.33 \rightarrow A$$

$$\therefore \omega_n^2 = \frac{300}{7.5} = 40$$

$$\therefore \omega_n = \sqrt{40} = 6.325 \text{ Hz (3dp)} \rightarrow B$$

$$\therefore 2\zeta \omega_n = 5.33 \quad \therefore \zeta = \frac{5.33}{2\omega_n} = 0.422 \rightarrow C$$

Hence, the system is underdamped.

$$4)2)B) \quad \% \text{ Peak overshoot} = \exp\left(\frac{-\zeta \pi}{\sqrt{1-\zeta^2}}\right) \times 100\%$$

$$= \exp\left(\frac{-0.422 \pi}{\sqrt{1-0.422^2}}\right) \times 100\%$$

$$= \cancel{23.205} 0.232 \times 100\%$$

$$= 23.205\% \text{ or } 23.21\% \text{ (2dp)} \text{ (3dp)}$$

Damped frequency of oscillation, $\omega = \omega_n \sqrt{1-\zeta^2}$

$$\therefore \omega = 6.325 \sqrt{1-0.422^2}$$

$$\omega = 5.735 \text{ Hz} \rightarrow D$$

4
2) B)
Continued

$$\text{Rise time: } \omega_{br} = \frac{\pi}{2} \therefore t_r = \frac{\pi}{2\omega} = \frac{\pi}{2 \times 5.735}$$

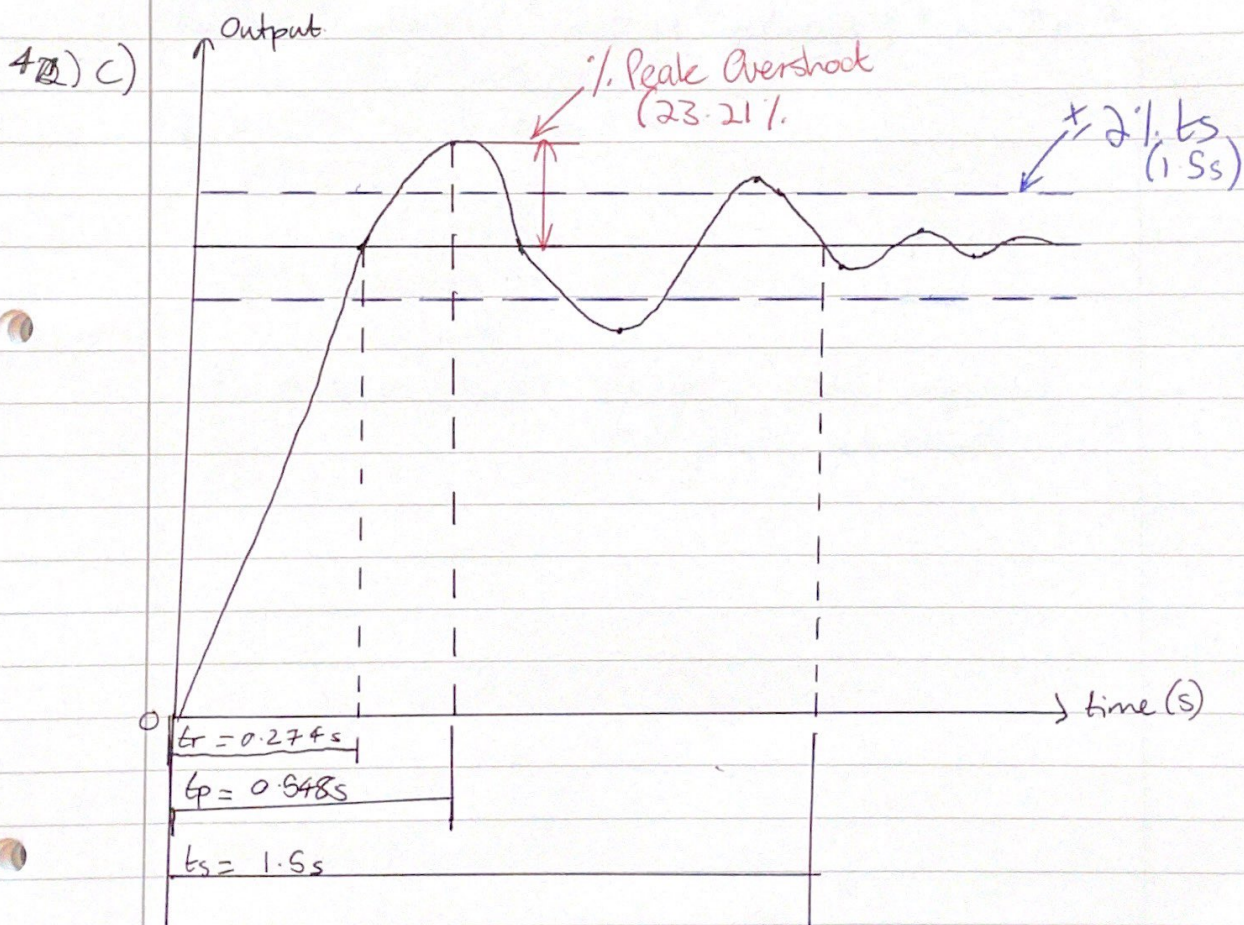
$$\therefore t_r = 0.274s \quad (3dp)$$

$$\text{Peale time: } \omega_{bp} = \frac{\pi}{\omega} \therefore t_p = \frac{\pi}{\omega} = \frac{\pi}{5.735}$$

$$\therefore t_p = 0.548s \quad (3dp)$$

$$2.1. \text{ Settling time: } t_s = \frac{4}{\zeta \omega_n} = \frac{4}{0.422 \times 6.325}$$

$$\therefore t_s = 1.5s$$



42) Percentage Peak overshoot = $\exp\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right) \times 100\%$

where, Percentage Peak overshoot = 15%

$$\therefore \frac{15\%}{100\%} = \exp\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right)$$

$$0.15 = \exp\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right)$$

$$\ln 0.15 = \ln \exp\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right)$$

$$\ln 0.15 = \left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right)$$

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

Square both sides

$$\ln 0.15^2 = -\zeta^2\pi^2 \quad \ln 0.15^2 - \ln 0.15 \zeta^2 = -\zeta^2\pi^2$$

$$\ln 0.15^2 = \ln 0.15 \zeta^2 - \zeta^2\pi^2$$

$$\ln 0.15^2 = 13.469 \zeta^2$$

$$\therefore \zeta^2 = \frac{\ln 0.15^2}{13.469}$$

$$\therefore \zeta = \sqrt{\frac{\ln 0.15^2}{13.469}}$$

$\zeta = 0.517$ (3dp) damping ratio required for 15% peak overshoot.