

Question 1

(a) Measuring is actually measuring the physical traits of something e.g. resistance or capacitance. Monitoring is associated with the sensors to observe, record or detect the values.

(b) There are two types of error

(i) Systematic error

(ii) Random error

Systematic error occurs due to the poor experimental methodology or design of the measurement system, where random error occurs due to the inability of the person carrying out the process.

(c) A strain gauge is a sensor whose resistance varies with applied force. When we apply the pressure, its resistance decreases, so according to pressure is measured.

The physical resistance is used in strain gauges to measure quantities such as pressure and temperature.

Question 1 cont

(d)

(i) Overall System Sensitivity

$$k_1 = 0.75^\circ/\text{rad}$$

$$k_2 = 150 \text{ mV/R}$$

$$k_3 = 500 \text{ V/V}$$

$$k_4 = 1.0 \text{ cm/V}$$

$$k = k_1 \times k_2 \times k_3 \times k_4$$

$$= 0.75 \times 150 \times 500 \times 1$$

$$= 56250 \times 10^{-5} \text{ m/rad}$$

$$k = 0.56 \text{ m/rad}$$

(ii) Angular displacement

$$\theta_i = \frac{1}{k} \cdot \theta_o$$

$$\therefore k = \frac{\theta_o}{\theta_i}$$

$$= \frac{0.085}{0.56}$$

$$\theta_i = 0.15 \text{ rad}$$

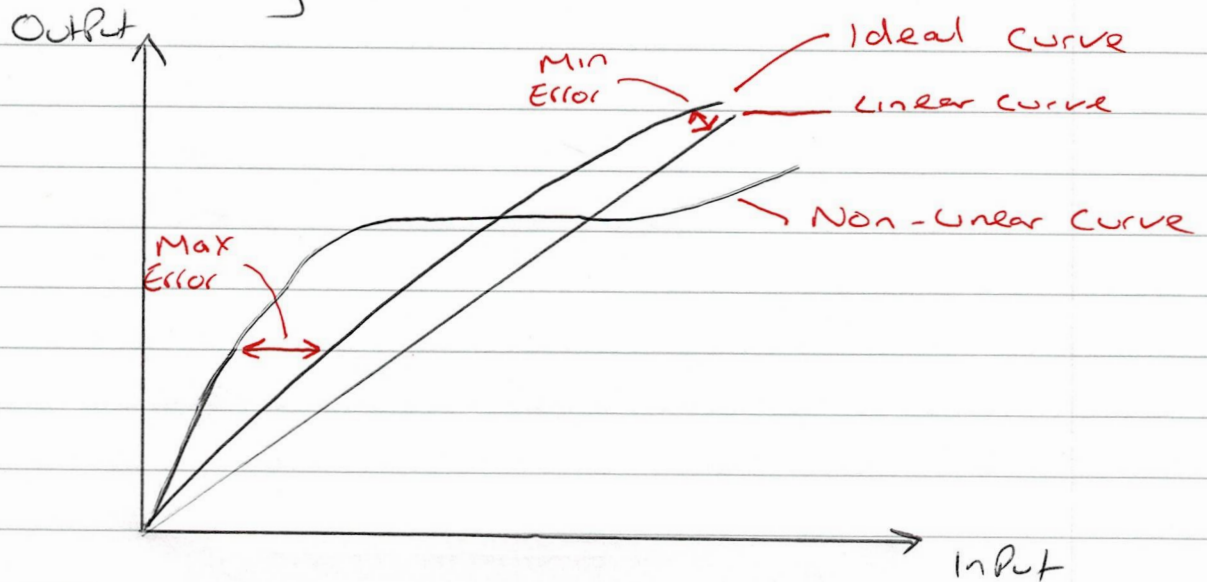
(iii)

A wheatstone bridge is an electrical circuit which is used to measure the unknown resistance. It has the ability to provide very accurate measurements.

Question 1 Cont

(e)

Non-linearity is the relationship between Output and Input (O/I) is a straight line. When the Output curve produces maximum error and is determined for either Input or Output quantity



Question 2

- (a) In an open loop system, the desired output does not depend on the control action. In a closed loop system, the desired output depends on the control action of the system.

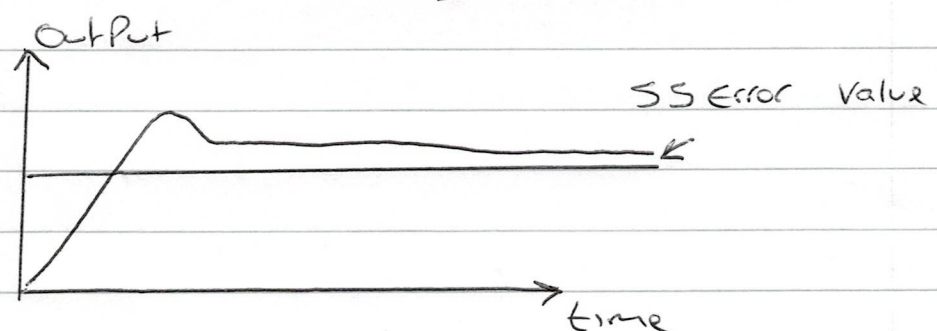
Open loopClosed loop

- ① Non feedback
- ② Components are controlled
- ③ Stable
- ④ Fast response
- ⑤ Non linear

- ① Feedback
- ② Components are amplified, Controller, Controlled Process, feedback
- ③ Less stable
- ④ Slow response
- ⑤ Linear

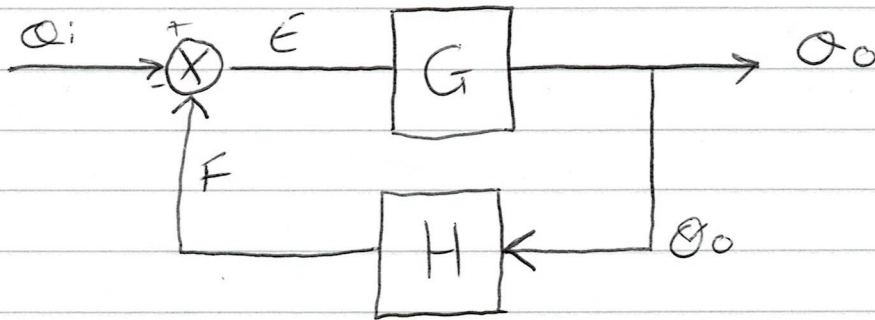
- (b) The Proportional Controller helps in reducing the Steady State error and helps to make the system more stable. It can also increase the speed of the response for the controller. Proportional control (P) produces control action which is proportional to the error signal (E). This will send a greater error signal to the actuator.

Disturbance error is associated with such a control mode. The higher the value of K_P , the less it will effect the disturbance. This controller cannot completely reduce the Steady State error.



Question 2 cont

(c)



$$G = \frac{O_o}{E} \Rightarrow E = \frac{O_o}{G}$$

 $\therefore$

$$H = \frac{F}{O_o} \Rightarrow F = H \cdot O_o$$

We know that :-

$$E = O_i - F$$

$$\therefore \frac{O_o}{G} = O_i - H \cdot O_o$$

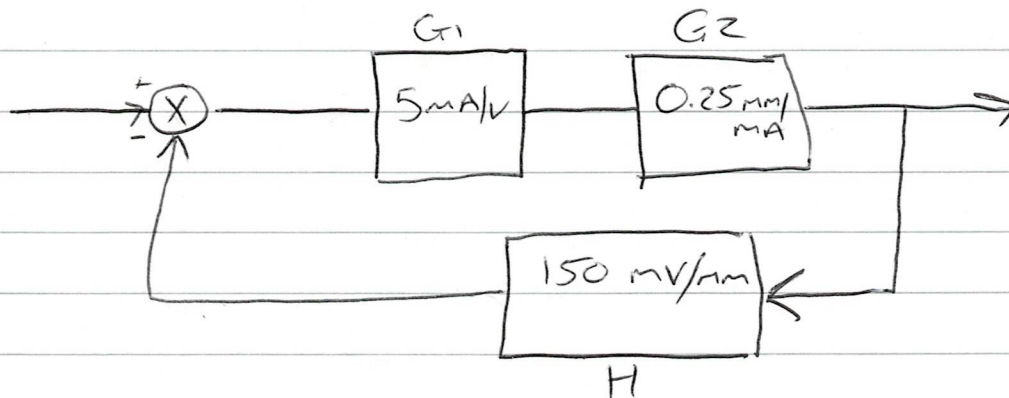
$$\therefore \frac{O_o}{G} + H \cdot O_o = O_i \Rightarrow O_o \left(\frac{1}{G} + H \right) = O_i$$

$$\Rightarrow O_o \left(\frac{1 + GH}{G} \right) = O_i$$

$$\frac{O_o}{O_i} = \frac{G}{1 + GH}$$

Question 2 cont

(d)



Overall transfer function of a closed loop

$$T(s) = \frac{G}{1+GH}$$

$$G = G_1 G_2 = (5 \text{ mA/V}) (0.25 \text{ mm/mA})$$

$$G = 1.25 \times 10^{-3} \text{ m/V}$$

$$T(s) = \frac{1.25 \text{ mm/V}}{1 + 0.18} = 1.05 \text{ mm/V}$$

(e) example 1 - A Steam Control Valve in a Thermal Power Station

example 2 - A temperature Control in a air Conditioning system.

Question 4

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

$$\frac{d^2 \theta_0}{dt^2} + 5.33 \frac{d\theta_0}{dt} + 40 \theta_0 = 106.6 \theta_i \quad (1)$$

(a) Comparing eq (1) with the standard form of equation:-

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

$$\Rightarrow 2 \zeta \omega_n = 5.33 \quad \omega_n^2 = 40 \Rightarrow \omega_n = 6.32$$

$$\zeta = \frac{5.33}{2 \times 6.32} = 0.42$$

As ζ is below 1, this tells us this is a underdamped system.

Question 4 cont

(b)

As calculated in part (a) $\zeta = 0.42$

$$\Rightarrow \% \text{ os} = e^{\frac{-\zeta \pi}{\sqrt{1-\zeta^2}}} \times 100$$

$$= e^{\frac{-0.42 \times 3.14}{\sqrt{1-(0.42)^2}}} \times 100$$

$$\% \text{ Over Shoot} = \underline{23.4 \%}$$

$$\Rightarrow \text{rise time} = ? \quad t_r = \frac{\pi}{\omega_d} \Rightarrow \omega_d = \omega_n \sqrt{1-\zeta^2} = 5.73$$

$$\Rightarrow t_r = \frac{3.14}{2 \times 5.73} \Rightarrow t_r = \frac{3.14}{2 \times 5.73} = \underline{0.27 \text{ sec}}$$

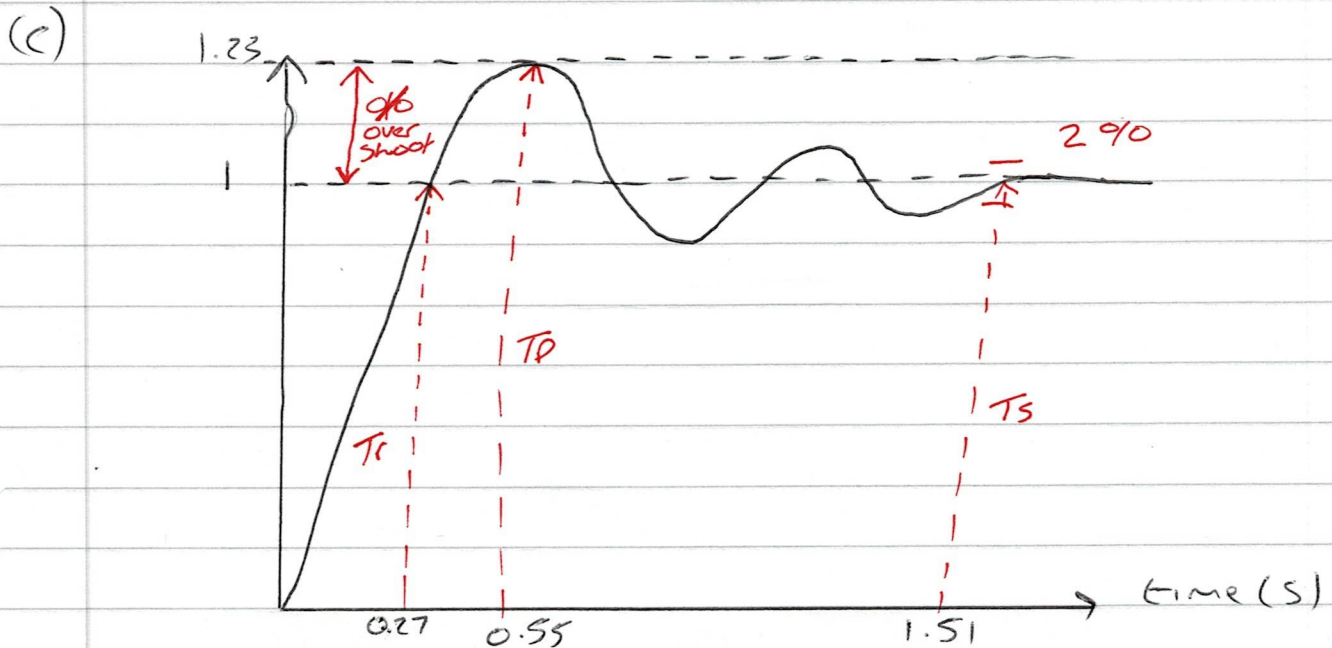
$$\Rightarrow \text{Peak time} = ? \quad t_p = \frac{\pi}{\omega_d} = \frac{3.14}{5.73}$$

$$\underline{t_p = 0.55 \text{ sec}}$$

$$\Rightarrow \text{Settling time of } 2\% = ?$$

$$T_s = \frac{4}{\omega_d} = \frac{4}{6.32 \times 0.42} = \underline{1.51 \text{ sec}}$$

Question 4 Cont



(d) %OS = 15%

$$\therefore \zeta = \frac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}}$$

$$= \frac{-\ln(0.15)}{\sqrt{3.14^2 + \ln^2(0.15)}}$$

$$\zeta = 0.51$$

This is the required damping ratio to achieve this criterion.