Question 1

(a) Measuring is actually measuring the Physical traits of something e.g resistance or Capacetance. 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 methodody or design of the measurment system, where random error occurs due to the inability of the Person carrying out the Process.

(c) A Strain guage is a Sensor who's resistance varies with applied force. When we apply the Pressure, it's resistance decreases, so according 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

$k_1 = 0.75\,\Omega/rad$

$k_2 = 150\ mV/\Omega$

$k_3 = 500\,V/V$

$k_4 = 1.0\ cm/V$

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

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

$= 56{,}250 \times 10^{-5}\ m/rad$

$k = 0.56\,m/rad$

(ii) Angular displacement

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

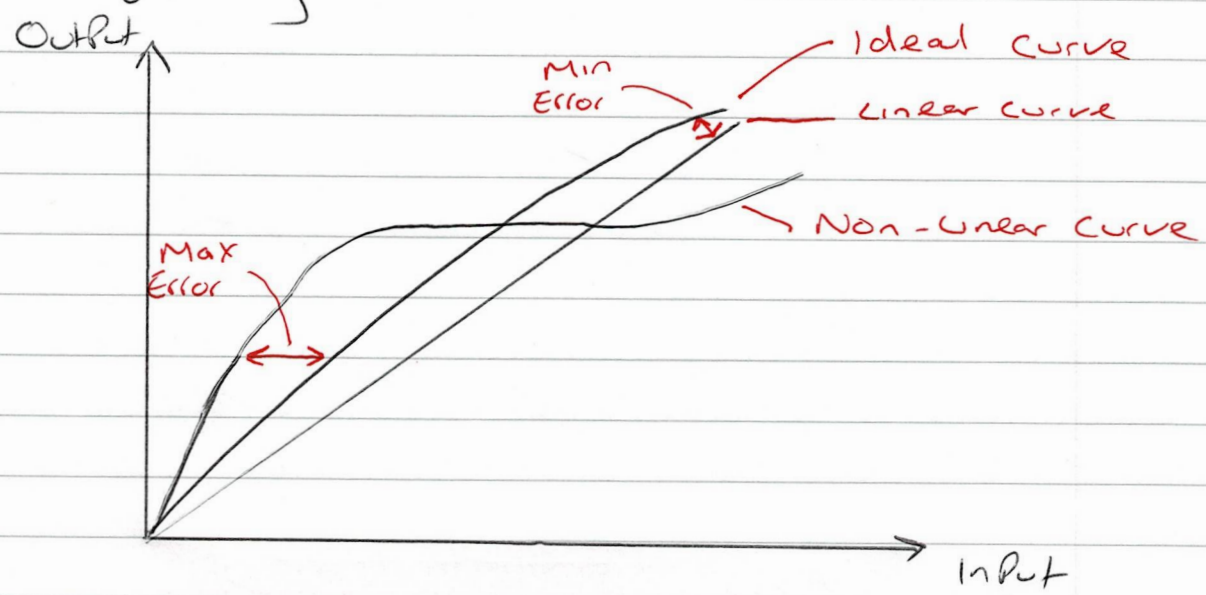
$= \frac{0.085}{0.56}$ $\theta_i = 0.15\ rad$

(iii) A wheatstone bridge is an electrical circuit which is used to measure the unknown resistance. it has the ability to provide very accurate measurments

Question 1 Cont

(e)

Non-linearity is the relationship between Out Put and input (OP/IP) is a Straight line. When the OutPut Curve Produces Maximum error and is determinded for either input or OutPut quantity

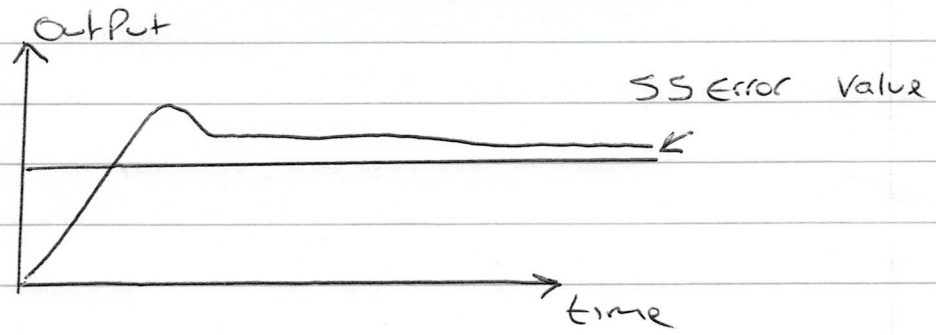


Question 2

(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

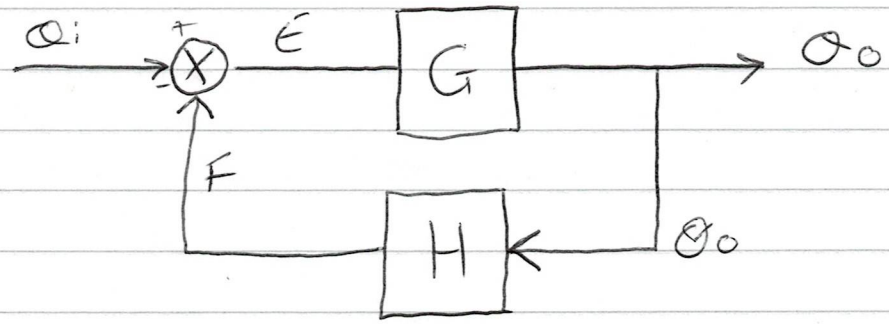
Open loop	Closed loop
① non feedback	① Feedback
② Components are controlled	② Components are amplified, Controller, Controlled Process, feedbac
③ Stable	③ less stable
④ Fast response	④ Slow response
⑤ non linear	⑤ Linear

(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 assosiated with such a control mode. The higher the value of KP, the less it will effect the disturbance. This controller cannot completly reduce the steady state error.



Question 2 cont

(c)



$$G = \frac{\theta_o}{\epsilon} \Rightarrow \epsilon = \frac{\theta_o}{G}$$

$\therefore$

$$H = \frac{F}{\theta_o} \Rightarrow F = H.\theta_o$$

we know that :-

$$\epsilon = \theta_i - F$$

$$\therefore \frac{\theta_o}{G} = \theta_i - H.\theta_o$$

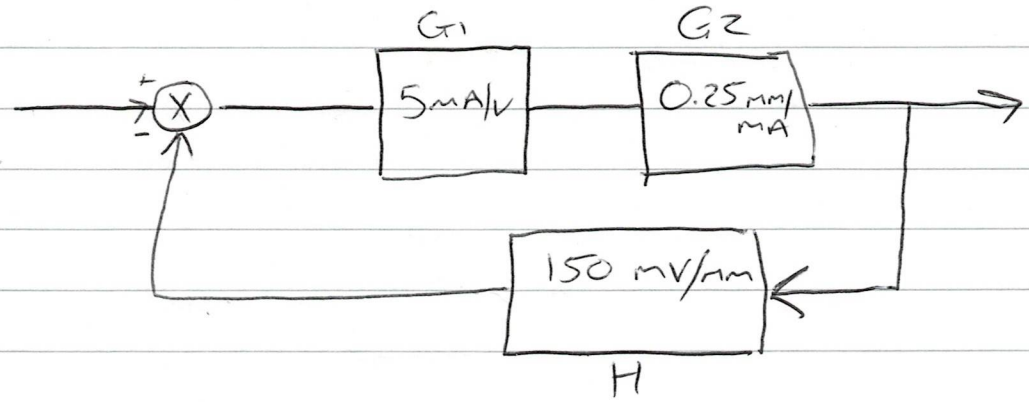
$$\therefore \frac{\theta_o}{G} + H.\theta_o = \theta_i \Rightarrow \theta_o\left(\frac{1}{G} + H\right) = \theta_i$$

$$\Rightarrow \theta_o\left(\frac{1+GH}{G}\right) = \theta_i$$

$$\frac{\theta_o}{\theta_i} = \frac{G}{1+GH}$$

Question 2 cont

(d)



Overall transfer function of a closed loop

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

$$G = G_1 G_2 = (5mA/V)(0.25mm/mA)$$

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

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

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

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

Question 4

$$7.5 \frac{d^2 Q_o}{dt^2} + 40 \frac{dQ_o}{dt} + 300 Q_o = 800 Q_i$$

$$\frac{d^2 Q_o}{dt^2} + 5.33 \frac{dQ_o}{dt} + 40 Q_o = 106.6 Q_i \quad (1)$$

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

$$\frac{d^2 Q_o}{dt^2} + 2\zeta\omega_n \frac{dQ_o}{dt} + \omega_n^2 Q_o = b_1 \omega_n^2 Q_i$$

$$\Rightarrow 2\zeta\omega_n = 5.33 \;\&\; \omega_n^2 = 40 \Rightarrow \omega_n = 6.32$$

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

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

Question 4 cont

(b)

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

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

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

% Overshoot $= 23.4\ \%$

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

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

$\Rightarrow$ Peak time $= ?$ $t_p = \frac{\pi}{\omega} = \frac{3.14}{5.73}$

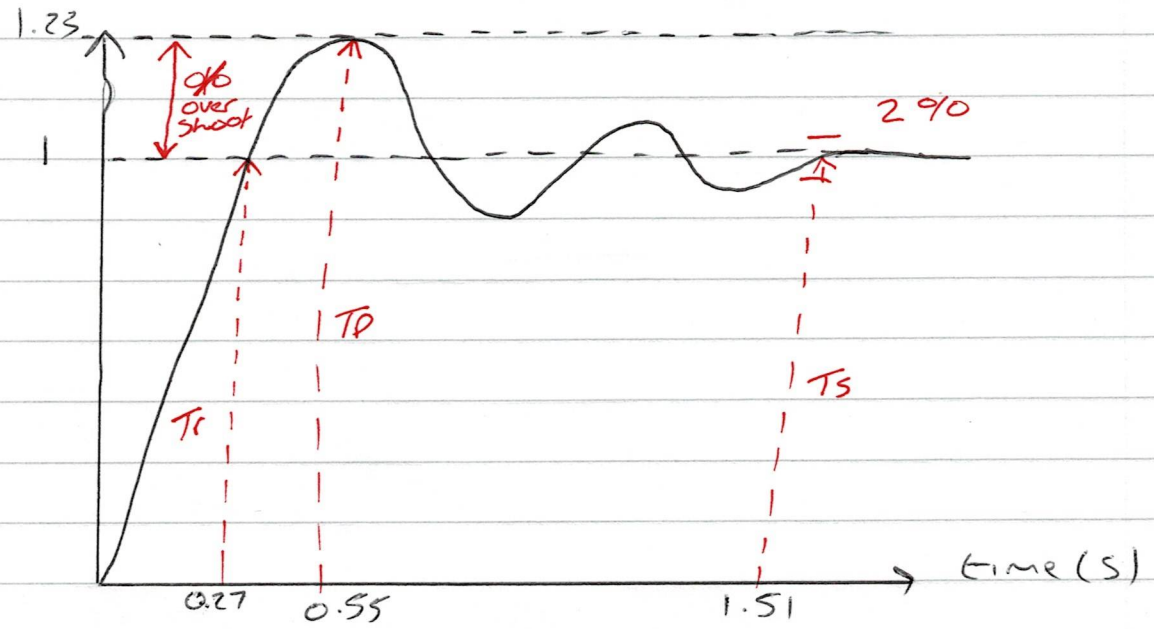
$t_p = 0.55$ sec

$\Rightarrow$ Settling time of 2% $= ?$

$T_s = \frac{4}{\zeta\omega_n} = \frac{4}{6.32 \times 0.42} = 1.51$ sec

Question 4 Cont

(c)



(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.