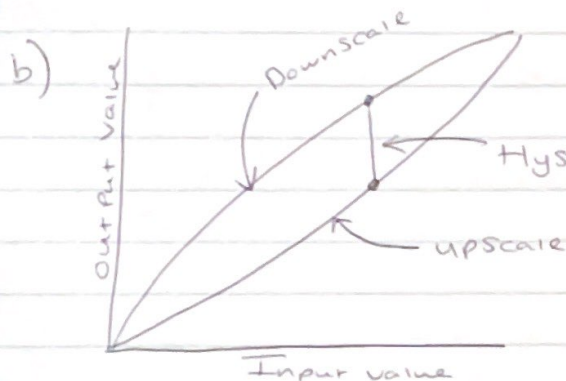


Question 1

a)



Hysteresis is ~~total~~ maximum difference in output for increasing & ~~total~~ decreasing values. Transducers can give different output value depending on whether the instrument is being loaded or unloaded.

c) Here A Strain gauge could be applied to a diaphragm which will result in a change in resistance with applied pressure.

Pressure forces the diaphragm to deform which causes the strain gauge to ~~change~~ change resistance. By the change in resistance we can calculate the amount of pressure applied.

$$d) i) \frac{C}{R} = (75 \times 10^{-3}) \times (150 \times 10^{-3}) \times 100 \times 1.78$$

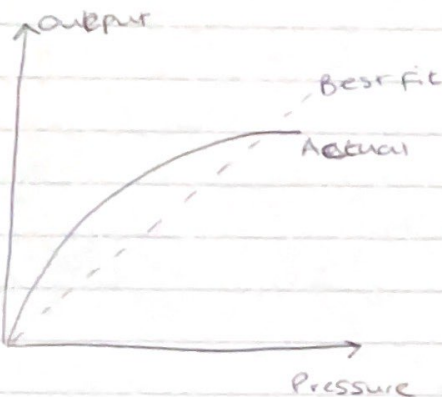
$$\therefore C/R = 200.25 \text{ cm/Rad}$$

ii)

iii) Changes resistance value into voltage to be read by Recorder

Question 1

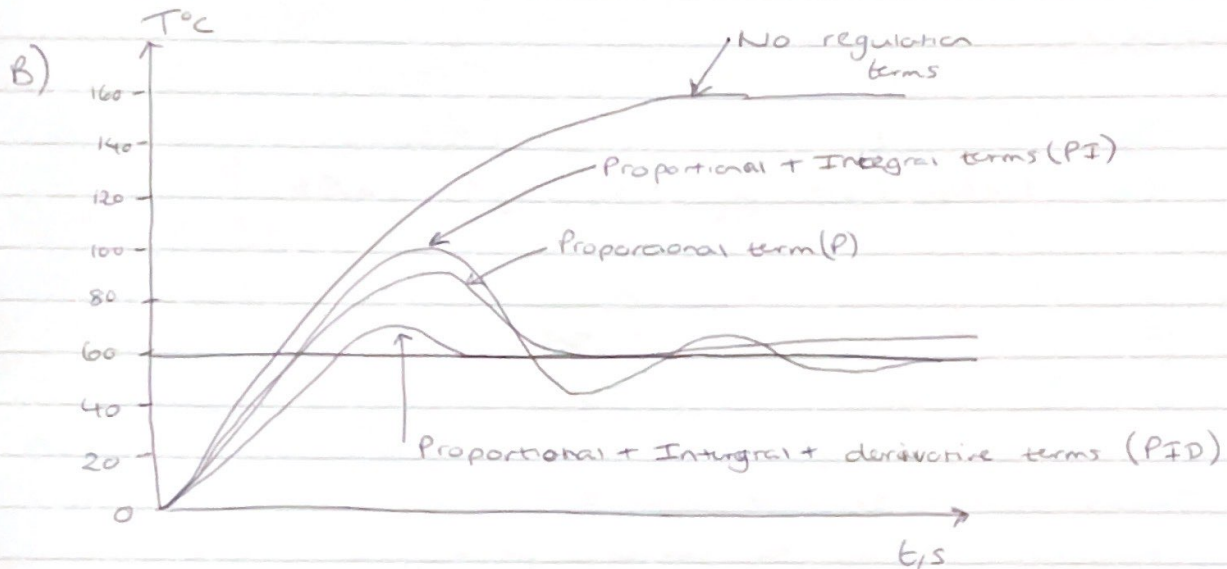
- e) Linearity error or non-linearity is the deviation of the sensor output curve from a specified straight line over a desired pressure range



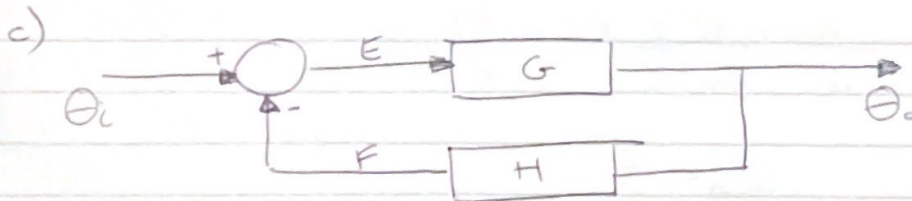
Question 2

- A) Control System manages, commands, directs or regulates the functions of other devices or systems using control loops. The benefits of automatic process control are it reduces overhead costs and unplanned downtime ~~which~~ by empowering operators with data to troubleshoot problems. It increases process usability by giving data through focused and customizable reporting. Increases production rate and productivity.
- b) PID controller is a combination of 3 control ^{modes} ~~processes~~ which enables a controller to have no offset error and reduces tendency for output oscillations.

Question 2



Temperature control of a heat treatment furnace is suited for the use of a PID



$$G = \frac{\Theta_o}{E} \Rightarrow E = \frac{\Theta_o}{G} \quad H = \frac{F}{\Theta_o} \Rightarrow F = H \cdot \Theta_o$$

$$E = \Theta_i - F$$

$$\therefore \frac{\Theta_o}{G} = \Theta_i - H \cdot \Theta_o \Rightarrow \frac{\Theta_o}{G} + H \cdot \Theta_o = \Theta_i$$

$$\text{So } \Theta_o \left(\frac{1 + G \cdot H}{G} \right) = \Theta_i \quad \text{Hence } \frac{\Theta_o}{\Theta_i} = \frac{G}{1 + G \cdot H}$$

Question 2

$$\begin{aligned}
 d) \quad \frac{Q_o}{Q_i} &= \frac{G_1 \cdot G_2}{1 + G_1 \cdot G_2 \cdot H} = \frac{(10 \times 2.5)}{1 + (10 \times 2.5 \times 0.015)} \\
 &= \frac{25}{4.75} \\
 &= \underline{\underline{118.75 \theta_i}}
 \end{aligned}$$

- e) • Speed control of conveyor belt
 • Temperature control of brewing process

Question 4

$$a) \quad \frac{d^2 x}{dt^2} + \frac{C}{m} \times \frac{dx}{dt} + \frac{R}{m} \times x = \frac{F}{m}$$

$$2 \gamma \omega_n = \frac{C}{m} \quad \omega_n^2 = \frac{R}{m}$$

$$\omega_n = \sqrt{\frac{R}{m}} = \sqrt{\frac{4000}{14.5}} = \underline{\underline{16.61 \text{ Hz}}}$$

$$\gamma = \frac{C}{2 \omega_n m} = \frac{200}{2 \times 16.61 \times 14.5} = \underline{\underline{0.415}}$$

System is underdamped

Question 4

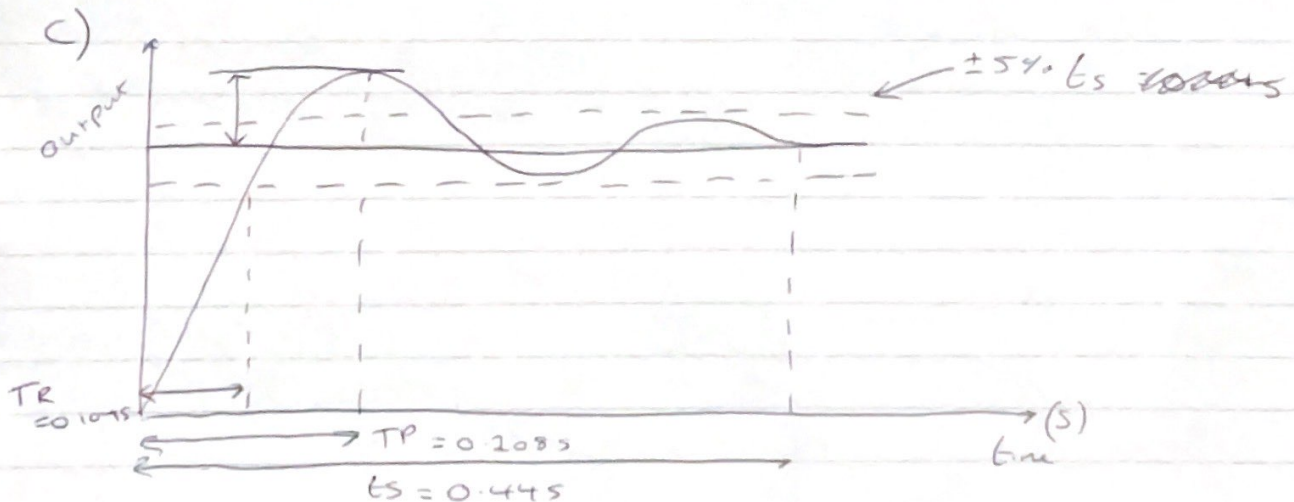
$$b) \% \text{ peak overshoot} = \left(\exp\left(\frac{-0.415\pi}{\sqrt{1-0.415^2}}\right) \right) \times 100\%$$

$$\begin{aligned} & \text{~~exp}(-1.304) = \text{exp} \frac{-1.304}{0.910} \times 100 \\ & = (\text{exp} -1.433) \times 100 \\ & = \end{aligned}~~$$

$$\text{Rise time, } t_r = \frac{\pi}{2\omega_n \sqrt{1-\zeta^2}} = \frac{\pi}{2 \times 16.6 \times 0.910} = 0.104 \text{ s}$$

$$\text{Peak time, } t_p = \frac{\pi}{\omega_n \sqrt{1-\zeta^2}} = 0.208 \text{ s}$$

$$5\% \text{ Settling time, } t_s = \frac{3}{\zeta \omega_n} = 0.440 \text{ s}$$



$$a) \text{ So } 12.5 = \left\{ e^{\frac{(-\pi \zeta)}{\sqrt{1-\zeta^2}}} \right\} \times 100$$

Taking natural logs of both sides

$$\ln 0.125 = \frac{-\zeta \pi}{\sqrt{1-\zeta^2}}$$

$$-2.079 - 2.081 \times (\sqrt{1-\zeta^2}) = -\zeta \pi \quad \text{Square both sides}$$

$$4.331 \times (1-\zeta^2) = 9.87 \times \zeta^2$$

$$4.331 = 13.469 \zeta^2$$

$$\zeta = \underline{\underline{0.567}}$$