

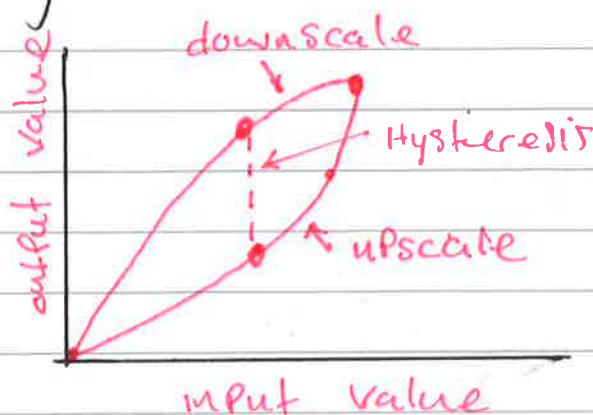
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a) The sensor produces an output which is related to the measurand known as the input and is generally proportional in nature. The signal conditioner receives the signal output and converts it into a format to be displayed.

b) hysteresis is when transducers give a different output value which depends on whether the instrument is loaded or unloaded. It is the maximum difference in output for increasing and decreasing values.



c) The change in pressure will be proportional to the change in resistance of the device.

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d)

K_1	$75 \text{ m}\Omega/\text{mm}$
K_2	$150 \text{ mV}/\Omega$
K_3	$100 \text{ V}/\text{V}$
K_4	$1.78 \text{ cm}/\text{V}$

i)

$0.075 \text{ }\Omega/\text{mm}$
$\cdot 150 \text{ V}/\Omega$
$100 \text{ V}/\text{V}$
$1.78 \text{ cm}/\text{V}$

$$0.075 \times 150 \times 100 \times 1.78$$

$$C/R = 2.0025 \text{ mm/cm} \quad \frac{\frac{\Omega}{\text{mm}} \times \frac{\text{V}}{\Omega} \times \frac{\text{V}}{\text{V}} \times \frac{\text{cm}}{\text{V}}}{\text{mm} \times \frac{\text{V}}{\Omega} \times \frac{\text{V}}{\text{V}} \times \frac{\text{cm}}{\text{V}}}$$

ii) $C = 12.75$

$$\therefore R = \frac{12.75 \text{ cm}}{2.0025 \text{ mm/cm}} = 6.367 \text{ mm}$$

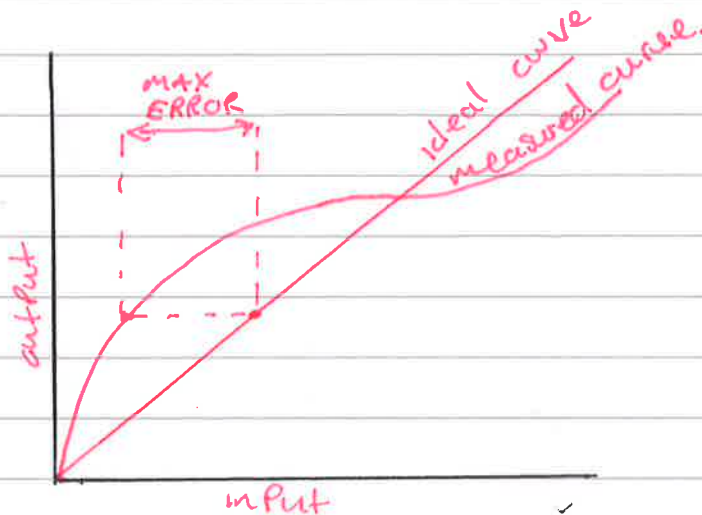
iii) The wheatstone bridge is used to convert a change in resistance into a corresponding change in voltage to provide accurate measurements.

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e)



when output curve is produced the max error is determined for either input or output quantity which is expressed as a % of the range.

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a) Control systems can be either open and closed systems. Their primary function is to adjust manipulated variables to the desired value or set point. They are used to control the output of a process. This is achieved by either manual intervention (open systems) or regulated by automatic means. (closed systems). The open loop system is inaccurate due to no correction for any disturbance. However, with the inclusion of a feedback loop ~~the~~ in a closed system, the input signal is affected by the system output. The input is then modified to maintain the output signal at required value.

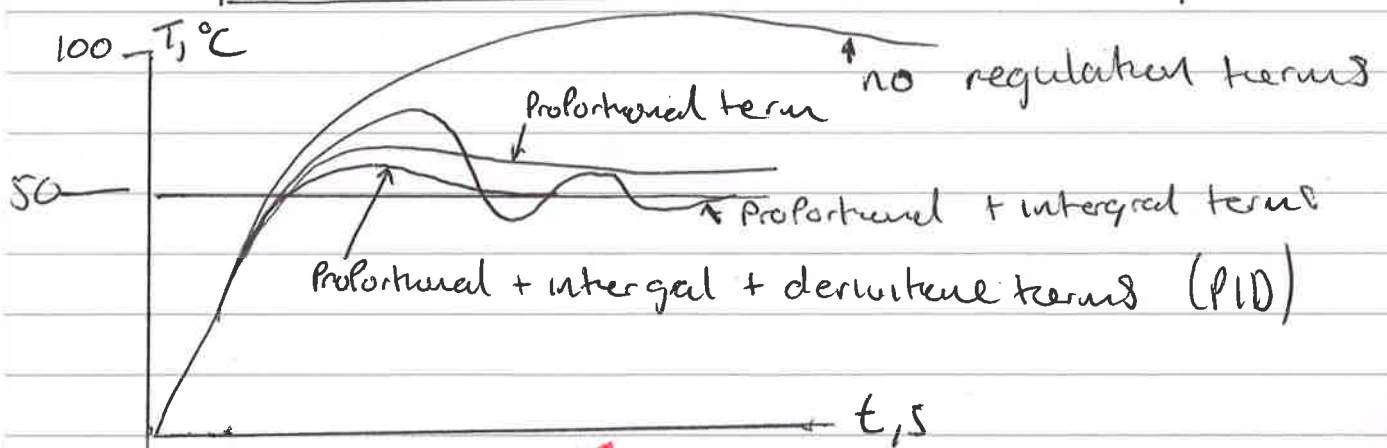
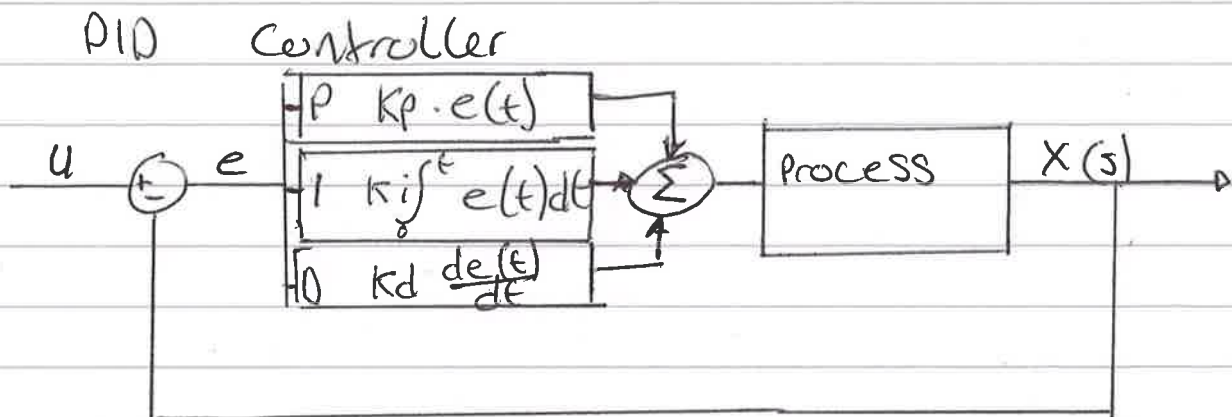
b). The PID controller is a combination of 3 control modes which enables a controller to have no offset error and reduced the tendency for output oscillations. Known as a 3-term controller. Proportional control (P), derivative control (D) and integral control (I).

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b) continued.

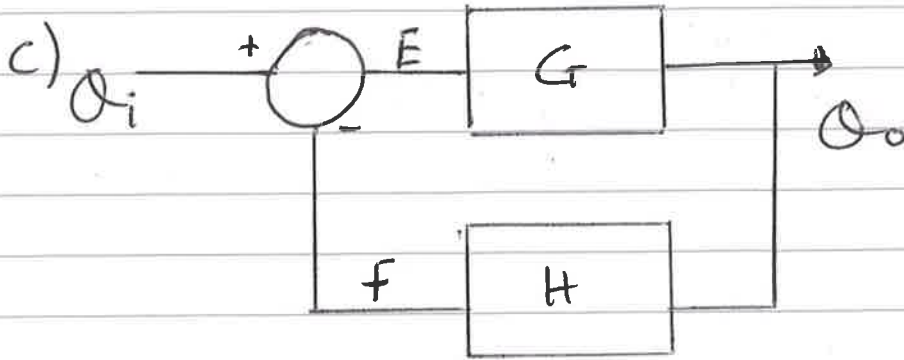


Response GRAPH

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$$G = \frac{Q_o}{E} \quad \therefore E = \frac{Q_o}{G}$$

$$H = \frac{F}{Q_o} \quad \therefore F = H Q_o$$

$$\therefore E = Q_i - F \quad \text{So, } \frac{Q_o}{G} = Q_i - H Q_o$$

$$\frac{Q_o}{G} + H Q_o = Q_i$$

$$\text{So, } Q_o \left(\frac{1 + GH}{G} \right) = Q_i$$

which proves = $\frac{Q_o}{Q_i} = \frac{G}{1 + GH}$

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$$\begin{aligned} d) \quad \frac{Q_o}{Q_i} &= \frac{G_1 G_2}{1 + G_1 G_2 H} \\ &= \frac{(10 \times 2.5)}{1 + (10 \times 2.5 \times 0.150)} \end{aligned}$$

$$\therefore \frac{Q_o}{Q_i} = 5.263 \text{ mm/V}$$

- e) Two examples where a closed loop system can be used are.
Automatic water level control in a water system, and automatic shaft speed control of electric motor which will adjust due to load.

Four

- a) divide through by m to convert to given system differential equation to standard form as so:

$$\frac{m}{m} \frac{d^2 x}{dt^2} + \frac{C}{m} \frac{dx}{dt} + \frac{k}{m} x = \frac{F}{m}$$

Simplify and input data.

$$\frac{d^2 x}{dt^2} + \frac{200}{14.5} \frac{dx}{dt} + \frac{4000}{14.5} x = \frac{F}{14.5}$$

$$\frac{d^2 x}{dt^2} + \boxed{13.793} \frac{dx}{dt} + \boxed{275.8} x = \frac{F}{14.5}$$

$\therefore$ when compare with second order standard form.

$$\frac{d^2 x_0}{dt^2} + \boxed{2\zeta\omega_n} \frac{dx_0}{dt} + \boxed{\omega_n^2} x_0 = b_1 \omega_n^2 x_i$$

$$\therefore \omega_n = \sqrt{275.8} = 16.607 \text{ Hz}$$

$$\text{so, } \boxed{2\zeta\omega_n} = 13.793 \quad \therefore \zeta = \frac{\sqrt{13.793}}{16.607}$$

$$\zeta = 0.91 \quad \text{critically damped.}$$

Four

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

$\therefore$

$$\left[\exp \left(\frac{-0.91\pi}{\sqrt{1-0.91^2}} \right) \right] \times 100$$

$$\frac{-2.8588}{0.41460}$$

$$\frac{-2.8588}{0.41460} = -6.8951$$

$$\left[\exp (-6.8951) \right] \times 100$$

$$= 10.1\%$$

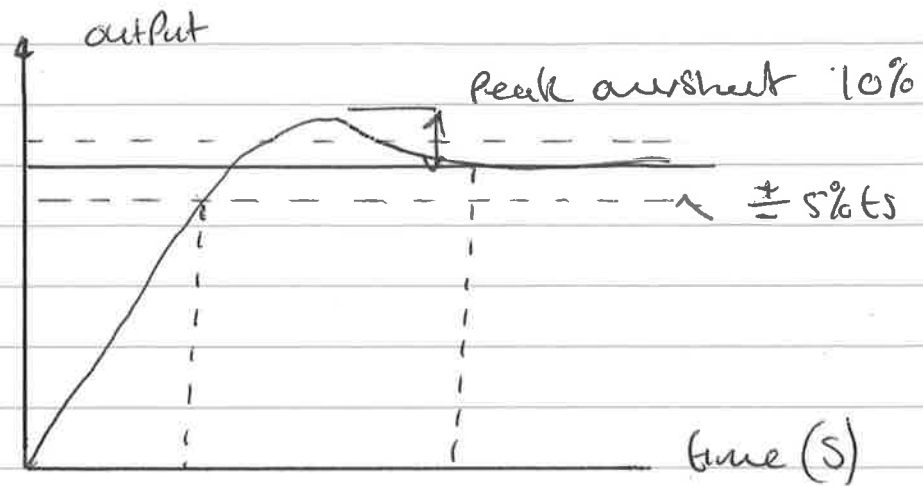
$$t_r = \frac{\pi}{2\omega_n \sqrt{1-\zeta^2}} = 0.228 \text{ sec Rise time}$$

$$t_p = \frac{\pi}{\omega_n \sqrt{1-\zeta^2}} = 0.456 \text{ sec Peak time}$$

$$5\% t_s = \frac{3}{0.91 \times 16.607} = 0.198 \text{ seconds}$$

Four

c)



d) 12.5%

$$\text{So, } 15 = \left[e^{\left(\frac{-\pi \zeta}{\sqrt{1-\zeta^2}} \right)} \right] \times 100$$

$$\ln .125 = \frac{-\zeta \pi}{\sqrt{1-\zeta^2}} \quad \text{Because take natural logs of both sides}$$

$$-2.079 (\sqrt{1-\zeta^2}) = -\zeta \pi$$

Square both sides to remove square root.

$$\therefore 4.3222 (1-\zeta^2) = 9.87 \zeta^2$$

$$\text{So } 4.3222 = 14.192 \zeta^2$$

$$\therefore \zeta = \sqrt{\frac{4.3222}{14.192}}$$

$$\zeta = 0.551 \quad \text{if the required value for Peak overshoot was 12.5\% .}$$