

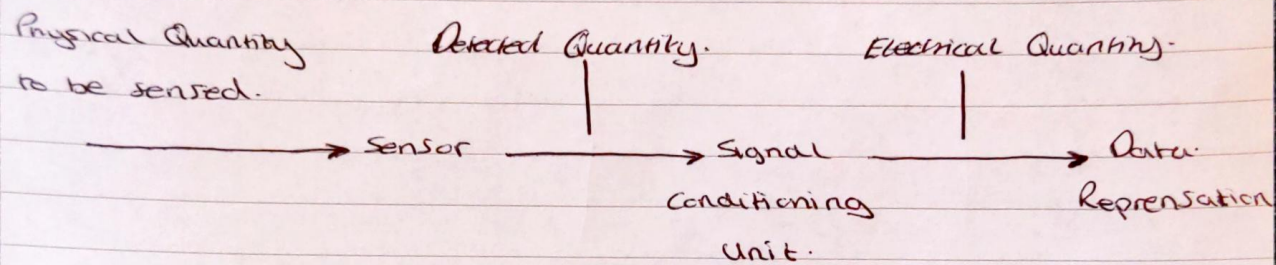
Question 1.

Scott Roberts.

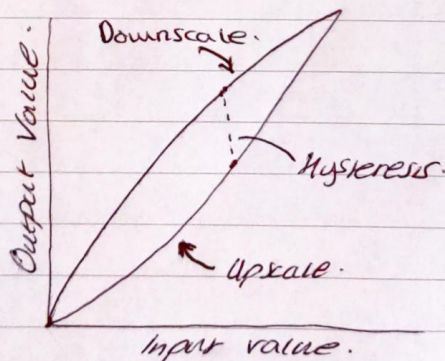
a) The transducers will convert a physical measurand into an electrical signal that can be converted into a digital signal.

The transducer will produce an output which is related to the measurand and is proportional in nature.

A recognised measuring word contain the following 3 elements:



b) Transducers can give different output value depending on whether instruments is being loaded or unloaded in terms of quantity being measured. Hysteresis error is maximum difference in output for increasing and decreasing values.



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c) The principle of the strain gauge is that is a pressure sensitive resistance. It has a resistance that changes value with applied pressure.

d)

$$i) 0.075 \text{ } \mu\text{m/mm} \times 0.150 \text{ } \mu\text{m}/\mu\text{m} \times 100 \text{ } \mu\text{m}/\mu\text{m} \times 1.78 \text{ cm}/\mu\text{m}.$$

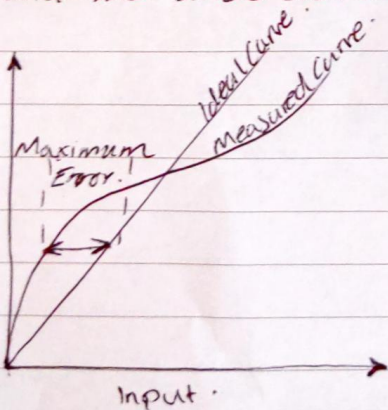
$$C/R = 2.0025 \text{ cm/mm}.$$

$$ii) = \frac{12.75}{2.0025}$$

$$L = 6.367 \text{ mm}.$$

ii) It is in position to measure unknown resistance. It then can convert that resistance into a corresponding voltage. It has the ability to provide very accurate measurements.

Non-linearity is the relationship of output/input linearity and the understanding that linearity is rare.



The graph plots the ideal curve and the actual curve. It is able to measure the maximum error. Analysing the relationship of the input and output.

The maximum error can be determined for either the input or the output quantity.

Question 2.

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- a) A control system is a set of electronic or mechanical devices that regulate other devices or systems through the use of control loops. The primary requirement of a control system is that a stable response is made to the input. The response must be made fairly fast and response must exhibit reasonable damping. A control system must also be able to reduce the system error to zero or to a value near zero.

Control systems are used widely in manufacturing industries for various reasons. Many reasons can be due to the increase in efficiency, the lack of delay and the responsive nature.

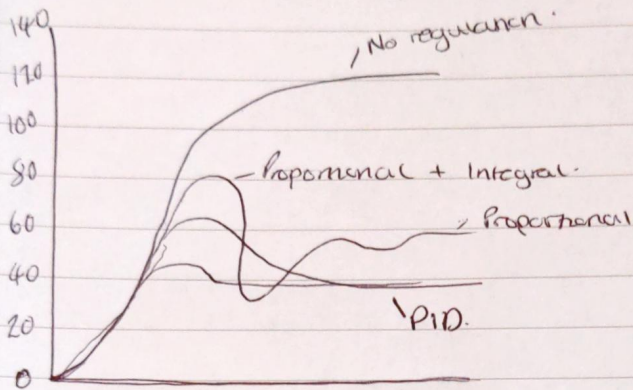
Control systems are also used widely to safely control processes and often will act as part of emergency shut down systems. This is due to the lack of human error. An example could be within high pressure reactor vessels, it would be likely there would be a control loop installed which would be receiving an input from a transducer measuring pressure. In the event of a high pressure reading the control unit could be programmed to activate an actuated valve to release pressure.

- b) PID is a combination of 3 controls modes, which enables a controller to have no offset error and reduce the tendency for output oscillation. The three controls modes which it has are proportional control, integral control and derivative control. Proportional control produces control action which is proportional to the error signal. An example would be the opening of an inter actuated valve to control level. This could allow marginal movements rather than open and close movements.

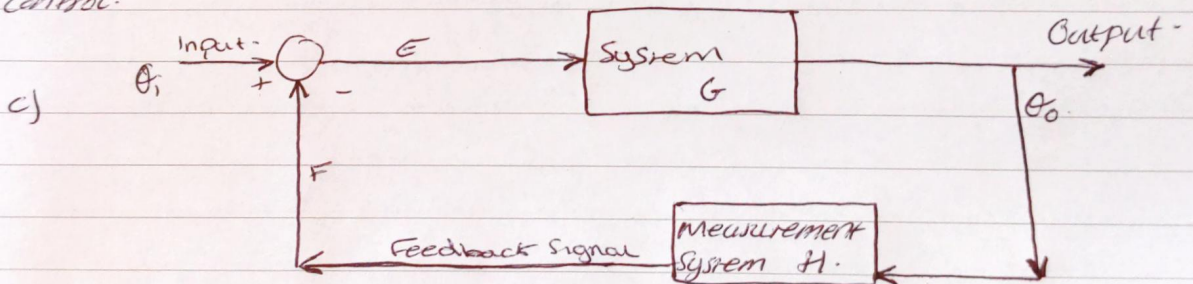
The derivative control mode allows for action to be produced proportional to the rate at which the error is changing.

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An integral control produces an action which will continue to increase as long as the error signal persists.



The graph demonstrates the reduction in oscillation due to the 3 control modes. This is why PIDs are widely used in the process industry to control operational plants. Purity is a process variable which is highly suited to the use of PID control.



$$d) \quad \theta_o = \frac{G}{1 + GH} = \frac{10 \times 2.5}{1 + (10 \times 2.5 \times 0.150)}$$

$$\theta_o = 5.26 \text{ mm/V.}$$

e.) Temperature control within a reaction vessel.
Raw material feed into a furnace.

Question 4.

a)

$$m \frac{d^2 x}{dt^2} + c \frac{dx}{dt} + kx = F.$$

Convert into standard form.

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

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

$$\text{So, } \omega_n^2 = \frac{k}{m}.$$

$$\zeta = \frac{200}{2 \times 16.61 \times 14.5}.$$

$$\omega_n^2 = \frac{4000}{14.5}.$$

$$\omega_n^2 = 275.86.$$

$$\omega_n = \sqrt{275.86}.$$

$$\omega_n = 16.61 \text{ Hz}.$$

$$\text{Answer } \zeta = 0.42.$$

System is underdamped.

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$$b) \% \text{ Peak Overshoot} = \left(\exp \left(\frac{-0.42\pi}{\sqrt{1-0.42^2}} \right) \right) \times 100.$$

$$\text{Answer} = 23.4\%.$$

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

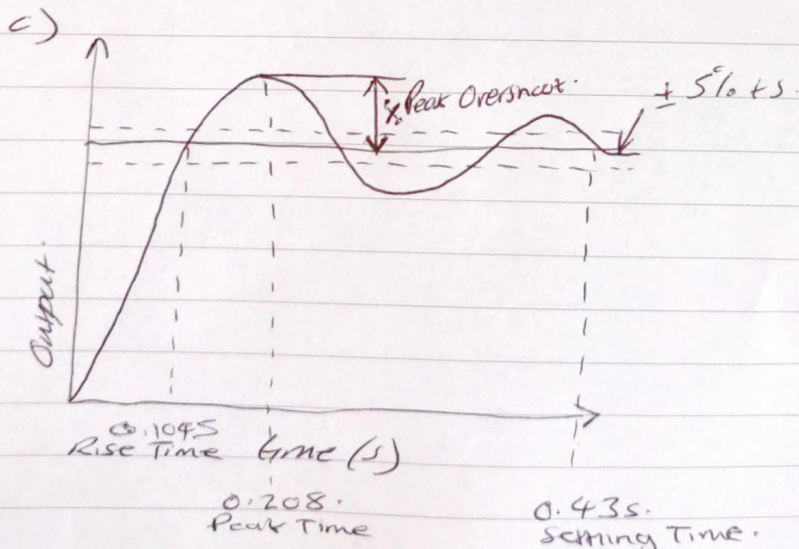
$$= 0.104 \text{ s.}$$

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

$$= 0.208 \text{ s.}$$

$$5\% \text{ settling time, } t_s = \frac{3}{\zeta\omega_n}.$$

$$= 0.43 \text{ s.}$$



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

$$= 23.3\%.$$

Taking natural logs of both sides.

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

$$-2.08 (\sqrt{1-\zeta^2}) = -\pi \zeta$$

$$4.3264 (1-\zeta^2) = 9.87 \zeta^2.$$

$$4.3264 = 14.1964 \zeta^2.$$

$$\zeta = 0.552 \text{ required value for } 12.5\% \text{ overshoot.}$$

$$\text{Answer} = 0.552.$$