

1a) A measurement is an act that quantifies a part or process. Examples of a measurement include length, speed or temperature. Monitoring is a process that observes measurements over time to detect trends or cycles.

b) The two types of error are random error and systematic error.

Random error - Random errors occur due to unpredictability or uncertainty in the measuring process. For example ~~or digital sensor~~ ~~or digital sensor~~ measuring an object at one temperature and then measuring at a different temperature will give you different readings. Random errors will vary the measurements.

Systematic error - Systematic errors occur due to a persistent issue in the measuring process. For example your micrometer not being properly zeroed before measuring. This will give a consistently wrong measurement.

Systematic are more avoidable than random errors, but systematic errors are also harder to spot.

c) A resistance strain gauge converts pressure into a change in electrical resistance which can then be measured. The physical parameter that's being utilised is the force of the pressure.

or

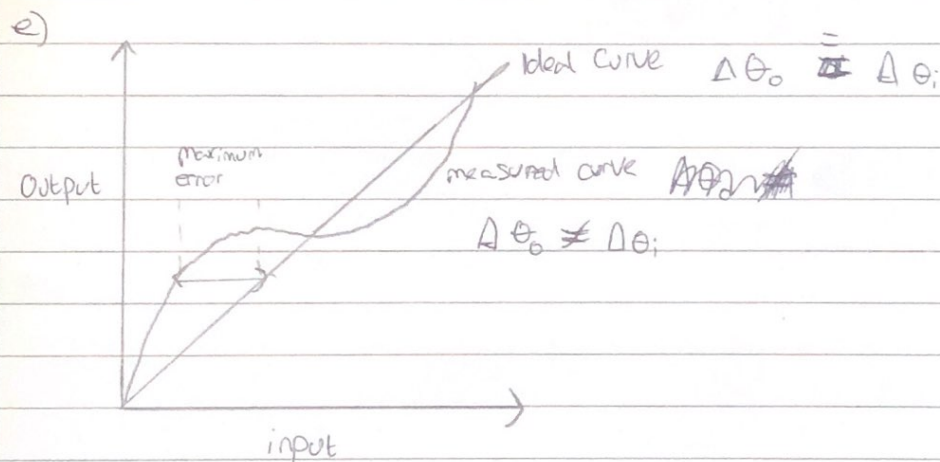
d) i)

|      |                        |                             |
|------|------------------------|-----------------------------|
| 0.75 | $\Omega / \text{Rad}$  |                             |
| 150  | $\text{mV} / \Omega$   | $= 0.15 \text{ V} / \Omega$ |
| 500  | $\text{V} / \text{V}$  |                             |
| 1    | $\text{cm} / \text{V}$ |                             |

$$0.75 \times 0.15 \times 500 \times 1 = 56.25 \text{ cm/Rad}$$

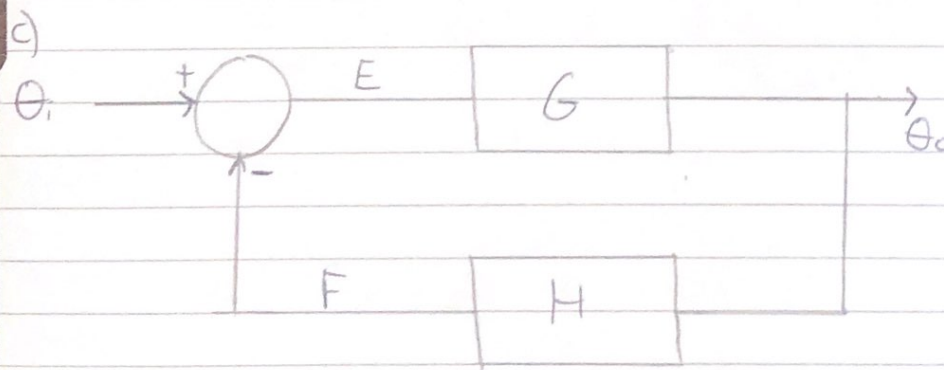
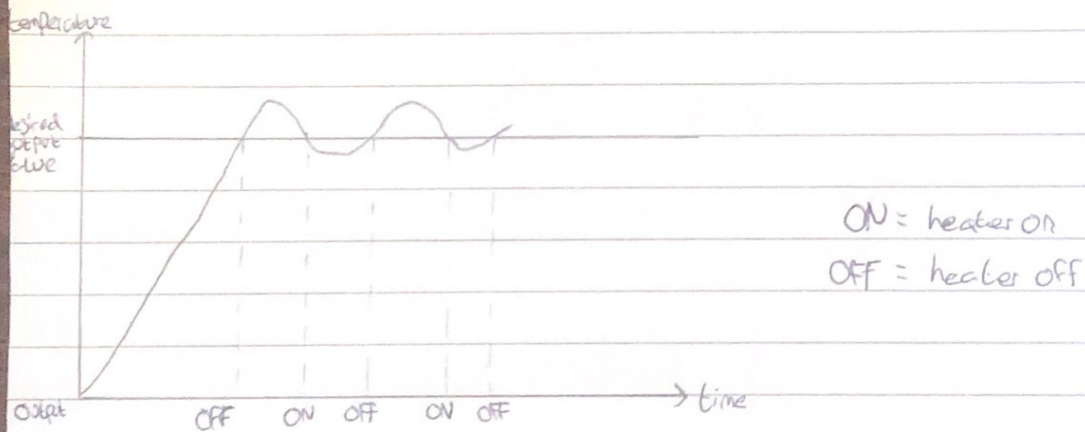
ii)  $R = \frac{8.5}{56.25} = 0.151 \text{ Rad}$

iii) The wheatstone bridge converts the resistance value into a voltage so it can be read by the recorder.



2-) An open loop system is a straight system comprised of an input value, a control unit, actuator, plant and output value. A closed loop system contains all of these but also has a measurement system to feed back to the input value to adjust for errors. An open loop system would have to be altered manually to get the desired output. A closed loop system utilises the feedback loop to alter the input value automatically to get the desired output. An example of an open loop system would be a toaster. An example of a closed loop system would be a digital thermostat.

b) proportional control graph is a control action that gives a correction value proportional to the error signal. So the larger the error the larger the correctional value will be to try and get the output value to the desired amount.



$$G = \frac{\Theta_o}{E} \quad \text{therefore} \quad E = \frac{\Theta_o}{G}$$

$$H = \frac{F}{\Theta_o} \quad \text{therefore} \quad F = H \cdot \Theta_o$$

$$E = \Theta_i - F \approx \frac{\Theta_o}{G} = \Theta_i - H \cdot \Theta_o$$

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

$$\Theta_i = \Theta_o \left( \frac{1 + G \cdot H}{G} \right) \approx \frac{\Theta_o}{\Theta_i} = \frac{G}{1 + G \cdot H}$$

d)  $G_1 = 5 \quad G_2 = 0.25 \quad H = 150 \text{ mV} = 0.15 \text{ V}$

$$\frac{\Theta_o}{\Theta_i} = \frac{G_1 \times G_2}{1 + (G_1 \times G_2 \times H)} = \frac{5 \times 0.25}{1 + (5 \times 0.25 \times 0.15)} = 1.053 \text{ mm/V}$$

e) Maintaining a temperature of a furnace.  
Controlling water tank levels.

4.) Standard

$$2 \zeta \omega_n = \frac{c}{m}$$

$$\frac{c}{m} = 40 \quad \frac{k}{m} = 300$$

$$2 \zeta \omega_n = \frac{c}{m} = 40 \quad \omega_n^2 = \frac{k}{m} = 300$$

$$\omega_n = \sqrt{300} = 17.32 \text{ Hz}$$

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

$$\frac{d^2 \theta_0}{dt^2} + 5.3 \frac{d\theta_0}{dt} + 40 \theta_0 = 106.6 \theta_0$$

$$2 \zeta \omega_n = \frac{c}{m} = \frac{40}{7.5} \quad \omega_n^2 = \frac{k}{m} = \frac{300}{7.5}$$

$$\omega_n = \sqrt{\frac{300}{7.5}} = 6.325 \text{ Hz}$$

$$\zeta = \frac{c}{2 \omega_n m} = \frac{40}{2 \times 6.325 \times 7.5} = 0.4216$$

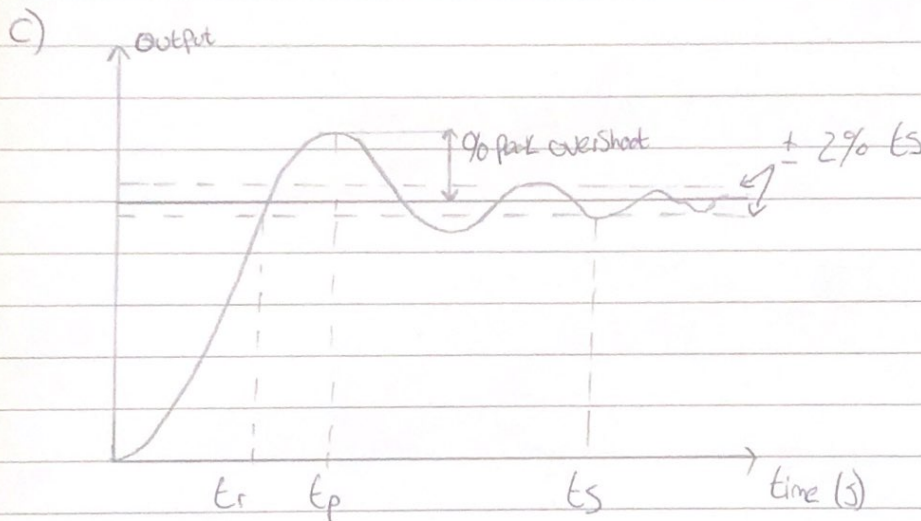
The System is underdamped

$$b) \% \text{ Peak overshoot} = \left( \exp \left( \frac{-0.4216\pi}{\sqrt{1-0.4216^2}} \right) \times 100 \right) = 23.20\%$$

$$\text{Rise time } (t_r) = \frac{\pi}{2\omega_n \sqrt{1-\zeta^2}} = \frac{\pi}{2 \times 0.4216 \times 6.325 \times \sqrt{1-0.4216^2}} = 0.274 \text{ s}$$

$$\text{Peak time } (t_p) = \frac{\pi}{\omega_n \sqrt{1-\zeta^2}} = \frac{\pi}{2 \times \sqrt{1-0.4216^2}} = 0.548 \text{ s}$$

$$2\% \text{ Settling time } (t_s) = \frac{4}{\zeta \omega_n} = \frac{4}{0.4216 \times 6.325} = 1.50 \text{ s}$$



$$d) 15 = \left( e^{\left( \frac{-\pi \zeta}{\sqrt{1-\zeta^2}} \right)} \right) \times 100$$

take natural logs of both sides.

$$\ln 15\% = \frac{-\pi \zeta}{\sqrt{1-\zeta^2}}$$

$$-1.897 = \frac{-\pi \zeta}{\sqrt{1-\zeta^2}} = 1.897 \left( \frac{\pi \zeta}{\sqrt{1-\zeta^2}} \right) = -0.4216\pi$$

now Square both sides

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$$3.599 (1 - \frac{\zeta^2}{0.216^2}) = 9.87 \times \frac{\zeta^2}{0.216^2}$$

$$3.599 = 13.469 \times \frac{\zeta^2}{0.216^2}$$

$$\frac{3.599}{13.469} = \zeta^2$$

$$0.267 = \zeta^2$$

$$\zeta = \sqrt{0.267} = 0.5167 \text{ for } 15\% \text{ peak overshoot}$$