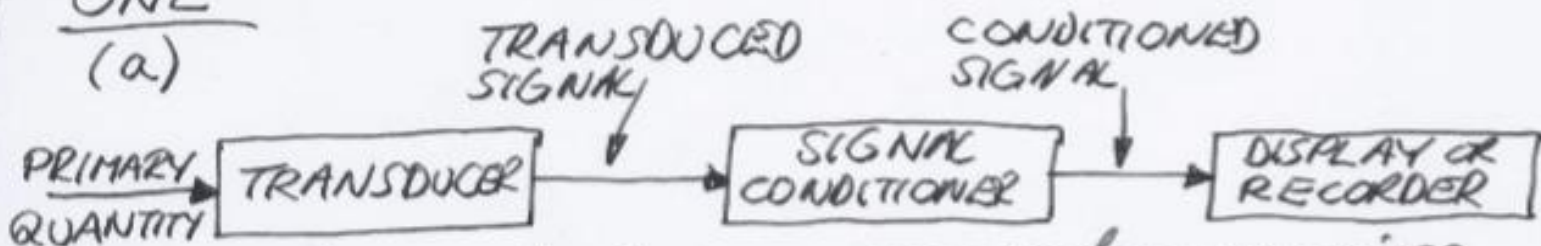


ONE
(a)



Transducer is energy converter; receives physical quantity being measured (measurand) and converts to some other physical variable. Signal conditioner rearranges transduced signal into form that can be readily recorded. Recorder used for recording and/or displaying information.

($\frac{1}{2}$ marks for blocks & signals; 3 marks functions).
(6 marks)

(b) **RESOLUTION**: smallest detectable change in instrument output, resulting from a change in input measured quantity.

THRESHOLD: minimum level of input required to produce an observable change in the instrument output.

(4 marks)

(c) Change in length of gauge wire causes proportional change in resistance of device.

(2 marks).

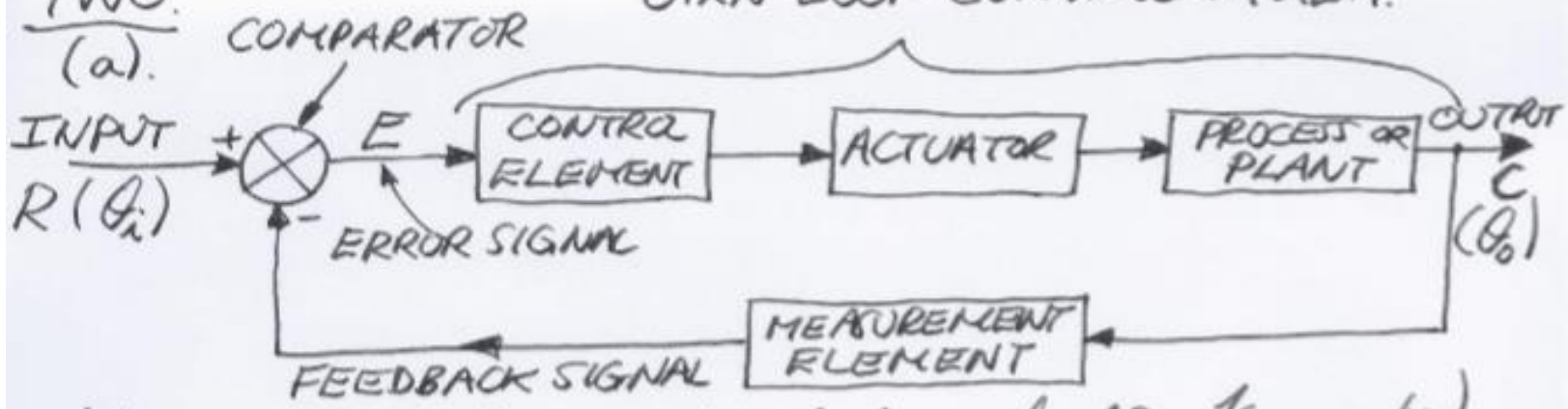
(d)(i) $\frac{C}{R} = 0.25 \times 0.1 \times 1000 \times 2.0$
 $\therefore \frac{C}{R} = 50 \text{ cm/rad.}$

(ii) Now, $C = 12 \text{ cm} \Rightarrow R = \frac{12}{50} = 0.24 \text{ rad.}$

(iii) Changes resistance value into voltage to be ultimately read by recorder. (6 marks)

(e) Maximum deviation from linear input/output relationship normally expressed as % of full-

TWO. OPEN-LOOP CONTROL SYSTEM.



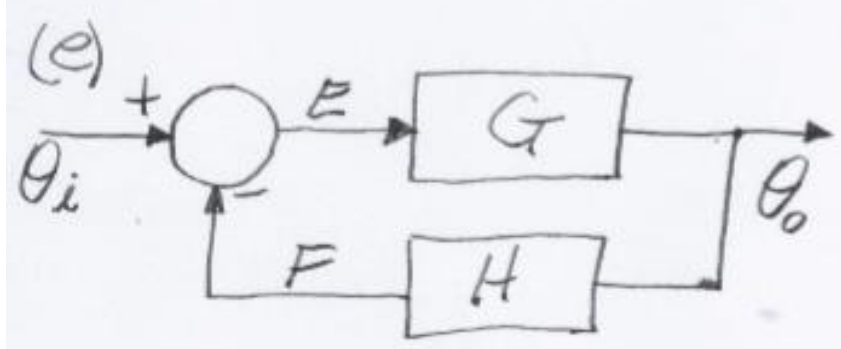
($\frac{1}{2}$ marks each for block/signal: $12 \times \frac{1}{2}$ marks). (6 marks).

- (b). Temp. control of heat treatment furnace,
 • Speed control of conveyor belt.
 (Any 2 suitable industrial examples). (2 marks).

- (c). Can automatically deal with system disturbance,
 • has reduced steady-state error. (2 marks).

(d) $\frac{\theta_o}{\theta_i} = \frac{0.1 \times 50}{1 + (0.1 \times 50 \times 0.02)}$

$\therefore \frac{\theta_o}{\theta_i} = 4.55 \text{ rpm/V}$ (4 marks)



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

Now, $E = \theta_i - F$
 $\therefore \frac{\theta_o}{G} = \theta_i - H \cdot \theta_o \Rightarrow \frac{\theta_o}{G} + H \cdot \theta_o = \theta_i$
 So, $\theta_o \left(\frac{1 + G \cdot H}{G} \right) = \theta_i$ Hence, $\frac{\theta_o}{\theta_i} = \frac{G}{1 + G \cdot H}$

THREE.

(a) From system d.e.;

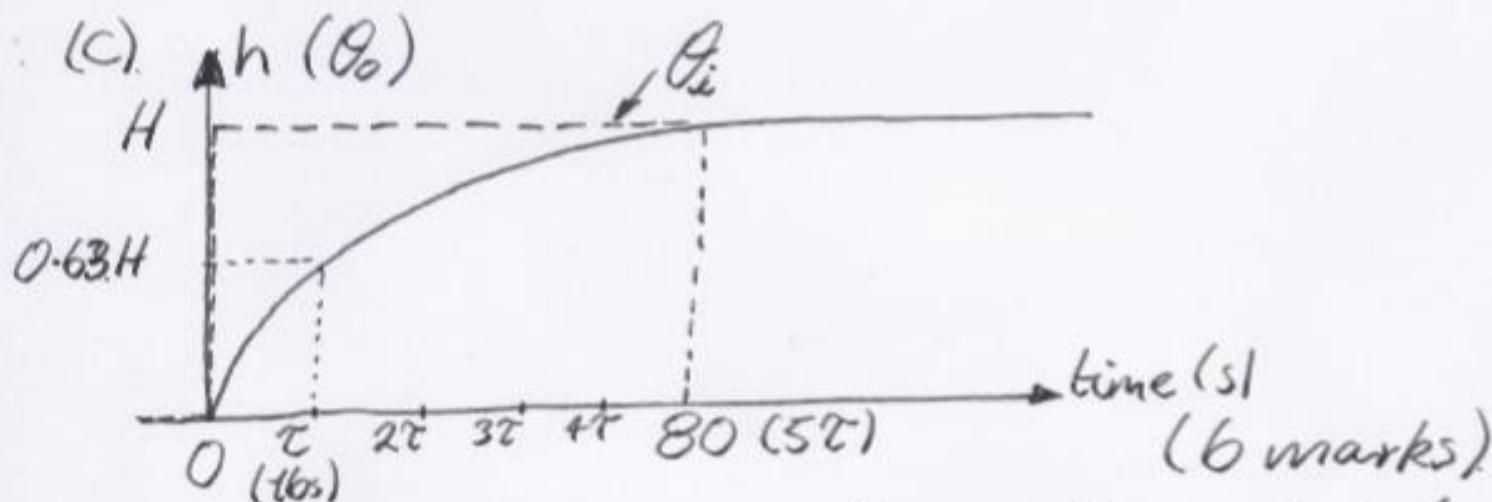
$$\frac{1}{k} = \tau \text{ (time constant); } h = \theta_0; H = G_s \theta_i$$

Substituting into standard formula;

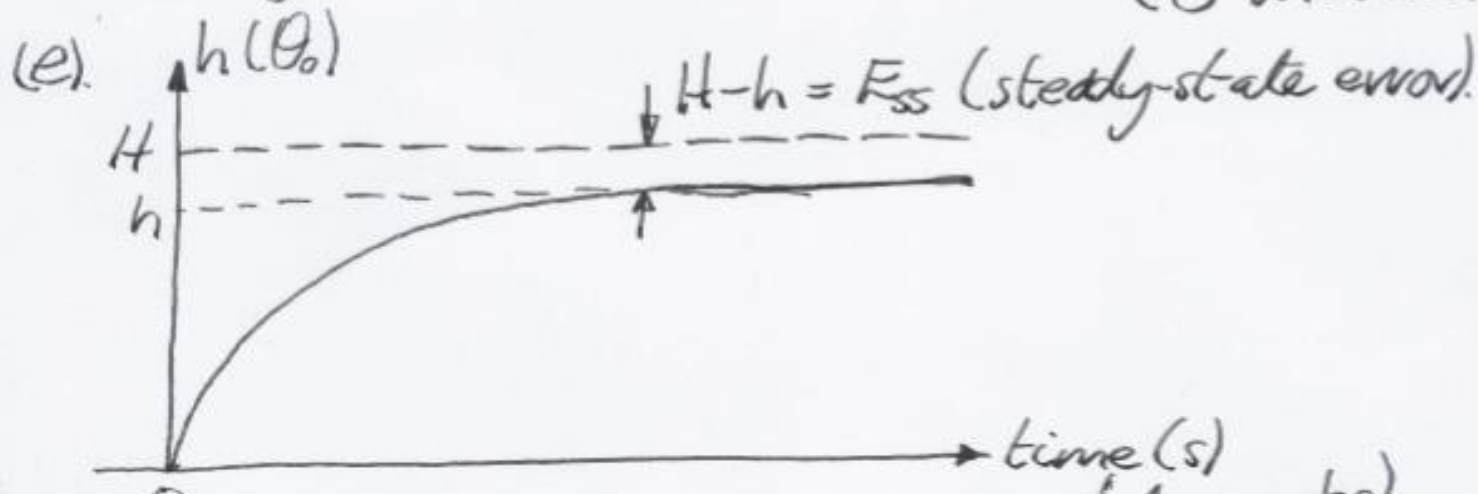
$$h = H. [1 - e^{-kt}] \quad (4 \text{ marks})$$

(b). $\tau = \frac{1}{0.0625} = 16s$ where, final value reached at approx. $5 \times$ time constant.

$$\therefore 5\tau = 80s \quad (3 \text{ marks})$$



(d). Water level (h) would not attain final value (H), hence there would be difference in the two values, i.e. $H-h$. This known as the steady-state error of the system (E_{ss}). (3 marks).



FOUR

(a) Convert system d.e. into standard form;

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

$$\text{So, } 2\zeta\omega_n = \frac{C}{m} \quad \text{and, } \omega_n^2 = \frac{k}{m}$$

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

$$\text{Now, } \zeta = \frac{C}{2\omega_n m} = \frac{40}{2 \times 6.325 \times 7.5} = 0.422$$

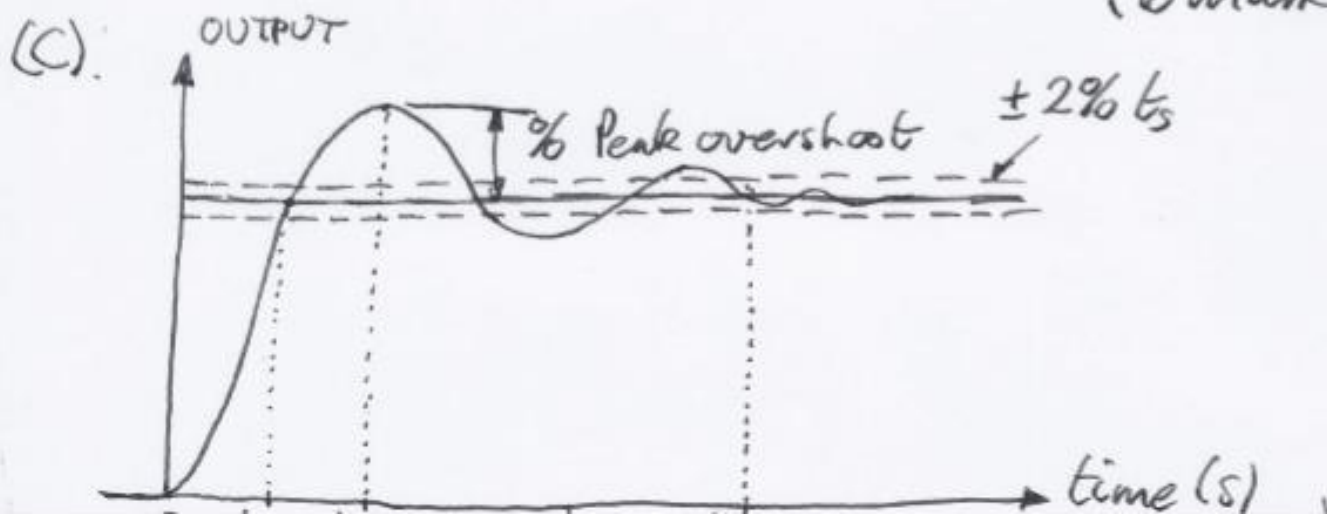
Hence, system is underdamped. (5 marks).

$$\begin{aligned} \text{(b) \% peak overshoot} &= \left(\exp\left(\frac{-0.422\pi}{\sqrt{1-0.422^2}}\right) \right) \times 100\% \\ &= 23.17\% \end{aligned}$$

$$\text{Rise time, } t_r = \frac{\pi}{2\omega_n \sqrt{1-\zeta^2}} = 0.274 \text{ s.}$$

$$\text{Peak time, } t_p = \frac{\pi}{\omega_n \sqrt{1-\zeta^2}} = 0.548 \text{ s.}$$

$$\text{2\% settling time, } t_s = \frac{4}{\zeta\omega_n} = 1.499 \text{ s.} \quad (6 \text{ marks}).$$



FOUR

(d). $S_0 \quad 15 = \left\{ e^{\left(\frac{-\pi \zeta}{\sqrt{1-\zeta^2}} \right)} \right\} \times 100$

taking Natural logs of both sides;

$$\ln 0.15 = \frac{-\zeta \pi}{\sqrt{1-\zeta^2}}$$

$$-1.897 \cdot (\sqrt{1-\zeta^2}) = -\zeta \pi \quad (\text{square both sides})$$

$$3.599(1-\zeta^2) = 9.87 \zeta^2$$

$$3.599 = 13.469 \zeta^2$$

$\therefore \zeta = 0.517$ (required value for
15% peak overshoot).
(5 marks).