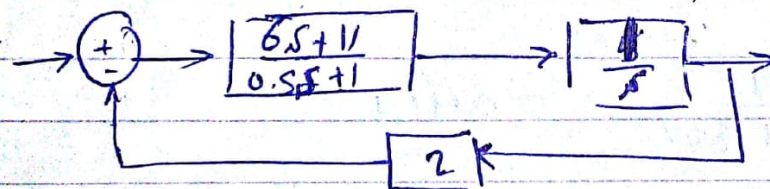


Mid term Exam

Q1

- Air cond.: Closed-loop has temp. sensor for feedback
- Cruise Control: Closed-loop has feedback for speed meas. & detection of ambient cond.
- Washing machine: open-loop time programmed, no feed.
- Time - controlled dryer: open-loop
- Camera-controlled Traffic Signal, closed-loop, has vision feedback

Q2



$$\frac{C}{R} = \frac{6s+11}{0.5s^2+13s+22}$$

for unit step $r(t)=1, t \geq 0 \Rightarrow R(s) = \frac{1}{s}$

$$C(s) = \frac{6s+11}{(0.5s^2+13s+22)s} = \frac{A}{s} + \frac{B}{s+24.1803} + \frac{C}{s+1.8197}$$

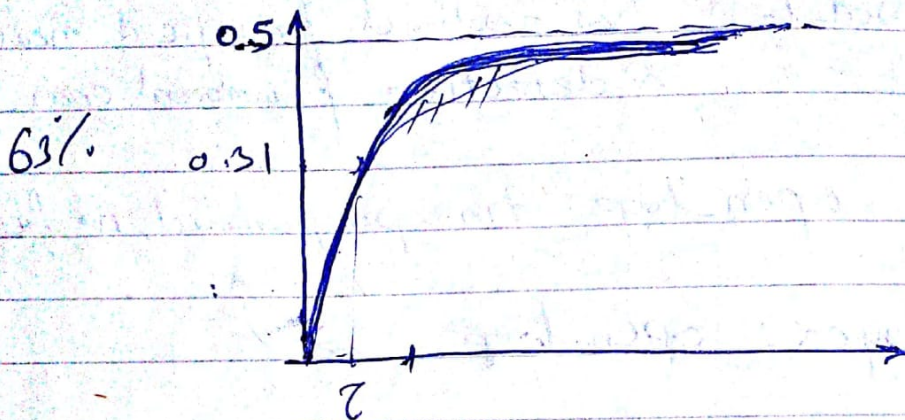
$$C(s) = \frac{6.5}{s} + \frac{-0.496}{s+24.1803} + \frac{-0.004}{s+1.8197}$$

$$C(t) = 0.5 - 0.496 e^{-24.1803t} - 0.004 e^{-1.8197t}$$

(2)

for plotting, the term $e^{-24.1803t}$ is too fast & can be ignored "If there was no zeros"

$\therefore c(t) \approx 0.5 - 0.004 e^{-1.88197t}$ "Will not work"



The zero effect "6.5+11" makes the system have an approximate effect of:-

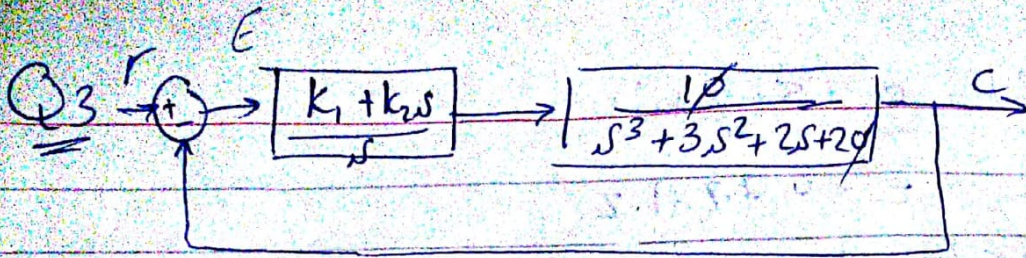
$$c(t) \approx 0.5 - 0.4\% e^{-24.1803t}$$

← ✓

$$\tau = \frac{1}{24.1803} = 0.0414$$

Other solutions are also considered.

3



$$\frac{C}{R} = \frac{1 \phi (k_1 + k_2 s)}{s^4 + 3s^3 + 2s^2 + 2 \phi s + 1 \phi k_2 s + 1 \phi k_1}$$

$$E = R - C$$

$$\frac{E}{R} = 1 - \frac{C}{R} = 1 - \frac{1 \phi k_1 + 1 \phi k_2 s}{s^4 + 3s^3 + 2s^2 + 2 \phi s + 1 \phi k_2 s + 1 \phi k_1}$$

$$\frac{E}{R} = \frac{s^4 + 3s^3 + 2s^2 + 2 \phi s}{s^4 + 3s^3 + 2s^2 + 2 \phi s + 1 \phi k_2 s + 1 \phi k_1}$$

for a ramp input $R(s) = \frac{1}{s^2}$

steady state error

$$e_{ss} = \lim_{t \rightarrow \infty} e(t) = \lim_{s \rightarrow 0} s E(s) = \lim_{s \rightarrow 0} s \cdot \frac{1}{s^2} \cdot \frac{s^4 + 3s^3 + 2s^2 + 2 \phi s}{s^4 + 3s^3 + 2s^2 + 2 \phi s + 1 \phi k_2 s + 1 \phi k_1}$$

$$e_{ss} = \lim_{s \rightarrow 0} \frac{s^3 + 3s^2 + 2s + 2 \phi}{s^4 + 3s^3 + 2s^2 + 2 \phi s + 1 \phi k_2 s + 1 \phi k_1}$$

$$e_{ss} = \frac{2}{k_1}$$

Q4 $G(z) = \frac{0.75(z+1)}{z^2 - 0.7z + 0.12}$

$$\frac{Y}{X} = \frac{0.75(z+1)}{z^2 - 0.7z + 0.12}$$

$$Y(z^2 - 0.7z + 0.12) = 0.75(z+1)X$$

$$y(k+2) - 0.7y(k+1) + 0.12y(k) = 0.75x(k+1) + 0.75x(k)$$

→
difference eqn.

$$Y(z) = \frac{0.75z(z+1)}{(z-1)(z^2 - 0.7z + 0.12)}$$

$$\frac{Y(z)}{z} = \frac{0.75(z+1)}{(z-1)(z-0.3)(z-0.4)} = \frac{A}{z-1} + \frac{B}{z-0.3} + \frac{C}{z-0.4}$$

$$Y(z) = \frac{3.5714z}{z-1} + \frac{13.9286z}{z-0.3} - \frac{17.5z}{z-0.4}$$

Assume $T=1$
 $-aT = -0.3$

$$y(k) = 3.5714 + 13.9286e^{-0.3k} - 17.5e^{-0.4k}$$

$aT = 0.4$
 $a = 0.916$

$$y(k) = 3.5714 + 13.9286(0.3)^k - 17.5(0.4)^k$$

for sketching

k=0	1	2	3	4	5	6	7	8	9	10	11	12
y=0	0.75	2.05	2.8	3.2	3.4	3.5	3.55	3.56	3.56	3.57	3.57	3.57

3.57

2

(5)

Q5 $C = G_2 M^*$

$$M = G_1 E^* \Rightarrow M^* = G_1^* E^*$$

$$\therefore C = G_2 G_1^* E^*$$

$$E = R - HC \Rightarrow E = R - H G_2 G_1^* E^*$$

$$\therefore E^* = R^* - \overline{H G_2 G_1^*} E^*$$

$$E^* (1 + \overline{H G_2 G_1^*}) = R^*$$

$$E^* = \frac{R^*}{1 + \overline{H G_2 G_1^*}}$$

$$\therefore C^* = \frac{G_2^* G_1^* R^*}{1 + \overline{H G_2 G_1^*}}$$

$$\therefore C(z) = \frac{G_1(z) \cdot G_2(z) \cdot R(z)}{1 + \overline{H G_2(z) \cdot G_1(z)}}$$

10

⑥

Q6 $F(z) = z^2 + (ck_p T + ck_i T - 2)z + (1 - ck_p T) = 0$

$a_2 = 1$

$a_1 = ck_p T + ck_i T - 2$

$a_0 = 1 - ck_p T$

$F(1) = 1 + ck_p T + ck_i T - 2 + 1 - ck_p T = 0$
 $= ck_i T > 0 \leftarrow \textcircled{1}$

$(-1)^2 F(-1) = 1 - ck_p T - ck_i T + 2 + 1 - ck_p T = 0$
 $= 4 - 2ck_p T - ck_i T > 0 \leftarrow \textcircled{2}$

$|a_0| < a_n$

$|1 - ck_p T| < 1 \Rightarrow 0 < ck_p T < 2$

Assume $T=1, c=10$

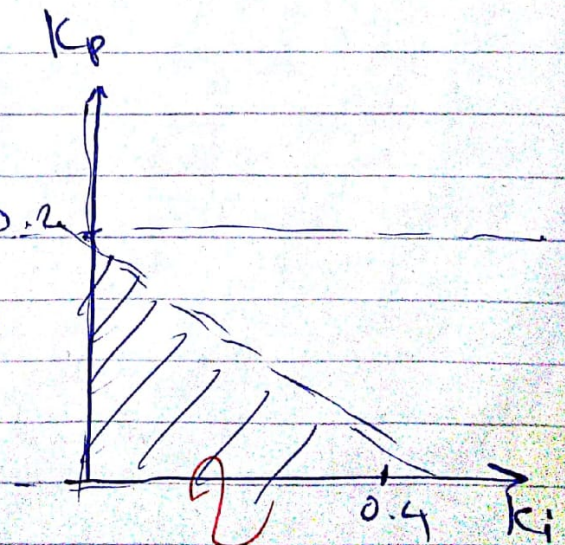
$10ki > 0 \leftarrow \textcircled{1}$

$4 - 20k_p - 10ki > 0 \rightarrow 0.2$

$k_p < -0.5ki + 0.2 \leftarrow \textcircled{2}$

$ck_p' < 10k_p < 2$

$0 < k_p < 0.2 \leftarrow \textcircled{3}$



Q.7

- $r(t)$ = reference signal 2
- $e(t)$ = error signal 2
- $m(t)$ = control signal 2
- $d(t)$ = disturbance 2
- $c(t)$ = output 2

