CD. Johnson Pg 536 ex 9.

PID

I/p range 0 – 4 V

O/p 0 – 8 V.

$k_p = 2.4\% / \%$

$k_I = 9\% (\%/min)$. min period = 8 sec.

$k_D = 0.7\% (\%/min)$.

Sol. $G_p = \frac{R_2}{R_1} = \frac{\cancel{2.4\% \text{ of } 4}}{} \cancel{\frac{8}{2.4\% \text{ of } 4}} \quad \frac{2.4\% \text{ of } 8}{1\% \text{ of } 4}$

$G_p = 4.8$

$k_I \%/(\%\text{-s}) = 9 \times \frac{1}{60} = 0.15\%/(\%\text{/s})$

$G_I = \frac{0.15\% \text{ of } 8}{1\% \text{ of } 4} = 0.3\ s^{-1}$

$k_D \%(\%/s) = \cancel{0.7 \times \frac{1}{60}} = \cancel{0.0116\%} = 0.7 \times 60 = 42\%$

$G_D = \cancel{\frac{0.0116\% \text{ of } 8}{1\% \text{ of } 4}} = \cancel{\frac{0.000928}{0.04}}$

$G_D = \frac{42\% \text{ of } 8}{1\% \text{ of } 4} = \frac{3.36}{0.04} = 84 \text{ sec}$

$2\pi f R_3 C_D = 0.1$

$2\pi R_3 C_D = (0.1)(8)$

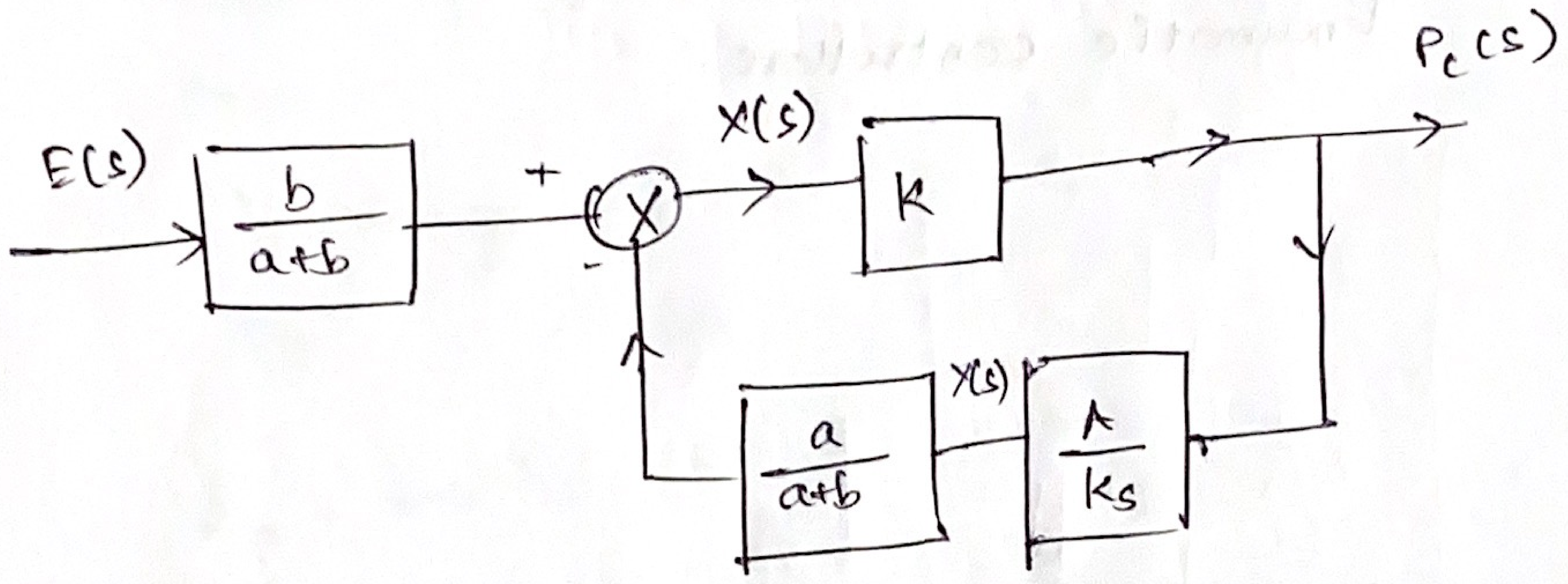
26/10/22

Pneumatic controllers.

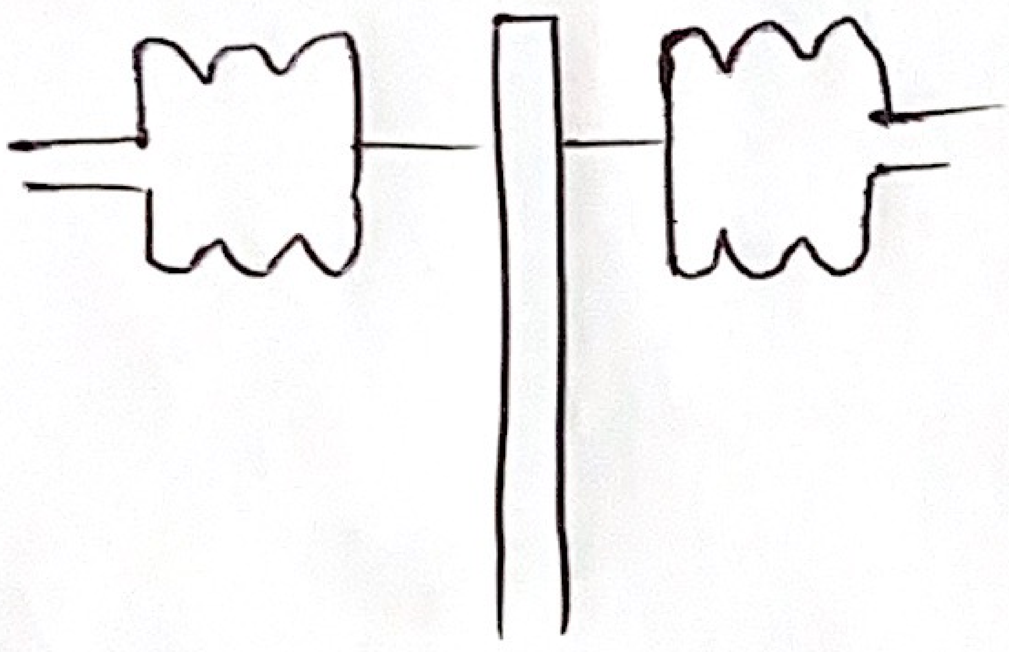
Proportional

$$x = \frac{b}{a+b} e - \frac{a}{a+b} y$$

$$\frac{P_c(s)}{E(s)} =$$



P controller (2nd method)



$$(P_{out} - P_o) A_2 x_2 = (P_{in} - P_{sp}) A_1 x_1$$

$$P_{out} = \frac{x_1 A_1}{x_2 A_2} (P_{in} - P_{sp}) + P_o$$

29/10/22

Tuning PID controllers

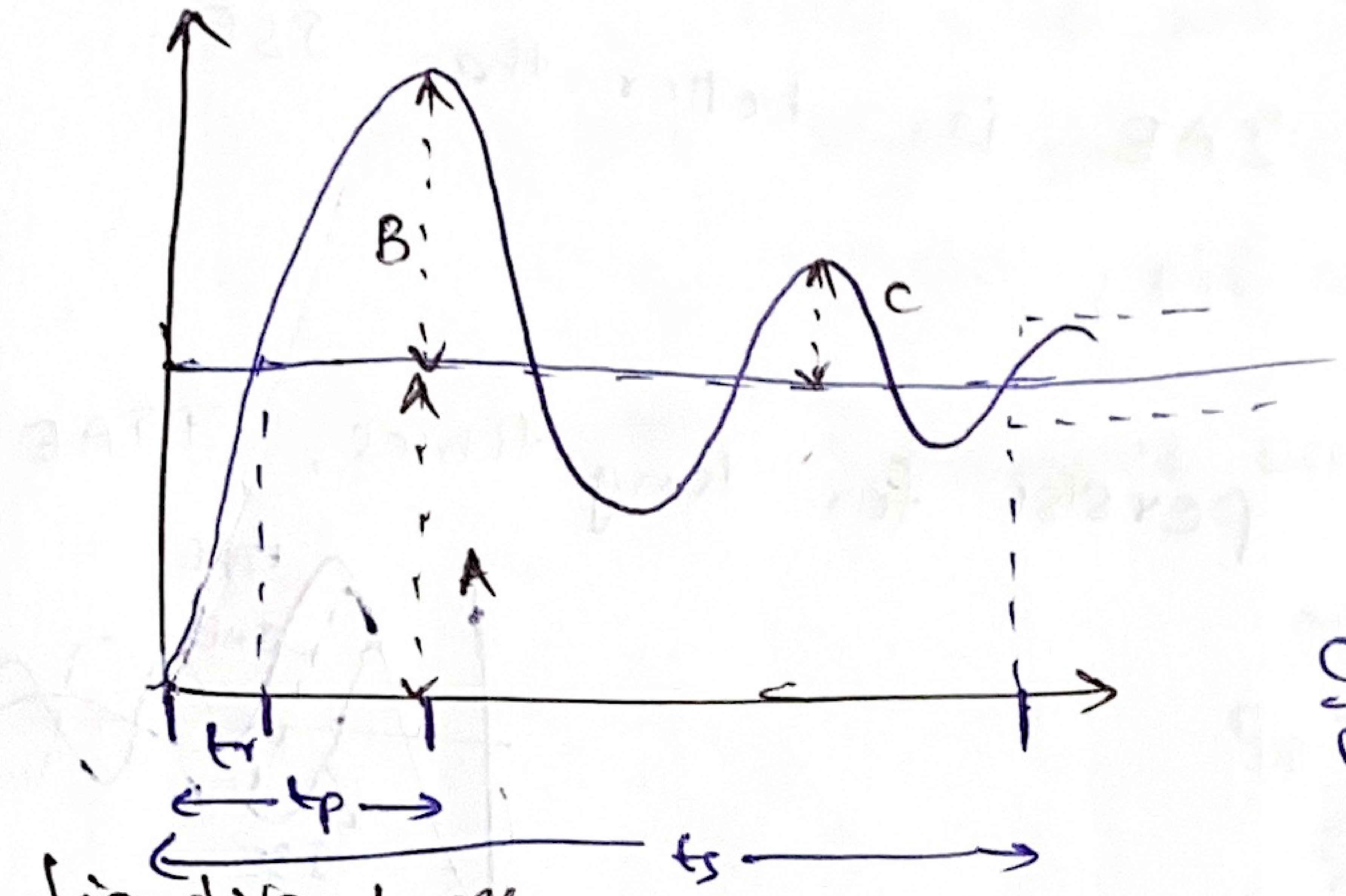
Disturbances
- Setpoint
- Load
- Noise

The process of experimentation for obtaining the optimum values of the controller parameters with respect to a particular process is known as controller tuning.

Simple Performance criteria.

6

One Quarter Decay Ratio criterion.



decay ratio $= \frac{C}{B} = \frac{1}{4}$

$$\frac{C}{B} = e^{-2\pi\xi / \sqrt{1-\xi^2}} = \frac{1}{4}$$

disadvantages.

fast rise time & reasonable settling time.

→ Responses with $\frac{1}{4}$ decay ratios are often judged to be too oscillatory by plant operators.

→ This criteria uses only two points of the response.

Alternative to this, that uses entire response.

Time Integral Performance criteria:

3 performance indices.

1. Integral of the square (ISE) error.

$$ISE = \int_0^\infty e^2(t) \cdot dt$$

2. Integral of the Absolute value (IAE) of the error

$$IAE = \int_0^\infty |e(t)| \cdot dt$$

3. Integral of the time-weighted absolute error (ITAE)

$$ITAE = \int_0^\infty t\,|e(t)| \cdot dt$$

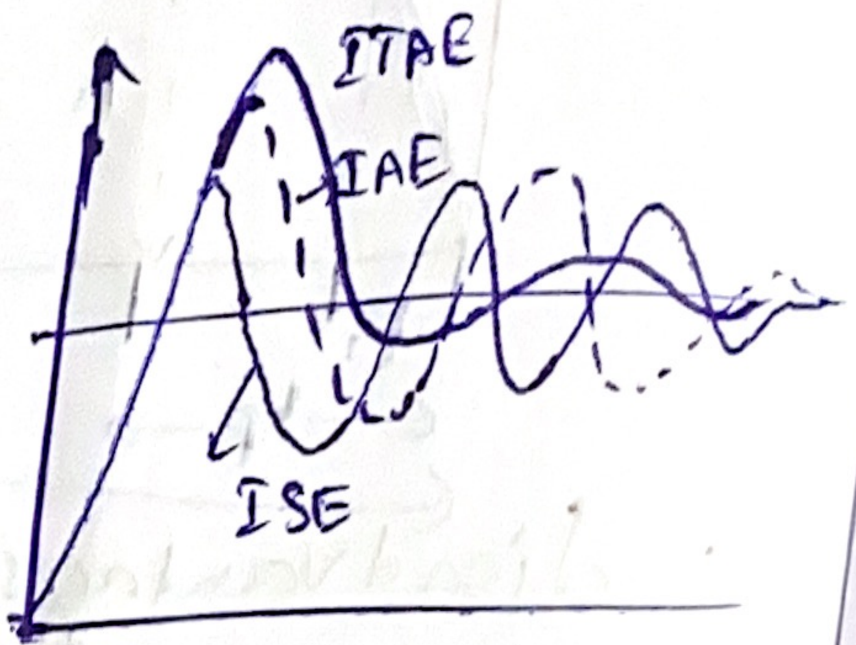
General guidelines

If you want to suppress

1. ~~for~~ large errors, ISE is better than IAE because errors are squared & contribute large values.

2. Small errors, IAE is better than ISE.

3. for errors that persist for long times, ITAE is better



Steps for selecting a feedback controller

1. Define an appropriate performance criteria

2. Compute those values of perfor. criteria using a P, PI or PID with best settings

3. Select the controller which gives the best value for the performance criterion.

Drawback of this procedure.

1. It is very tedious
2. It relies on the models of the process, sensor, FCE which can't be known exactly.
3. It incorporates certain ambiguities.

	P	I	D
flow	Always	Usually	Never
level	"	"	rare
temp	"	"	Usually
analytic.	"	"	Sometim
Pressure.	"	"	"

Prediction

ΔCp

K

Zeigle

Pmo

$k_p = \frac{\Delta}{N}$

PI

$k_p = 0.9$

$T_I = 3.3L$

PID

$k_p = 1.2 \frac{\Delta}{N}$

$T_I = 2L$

$T_D = 0.5L$

Controller tuning.

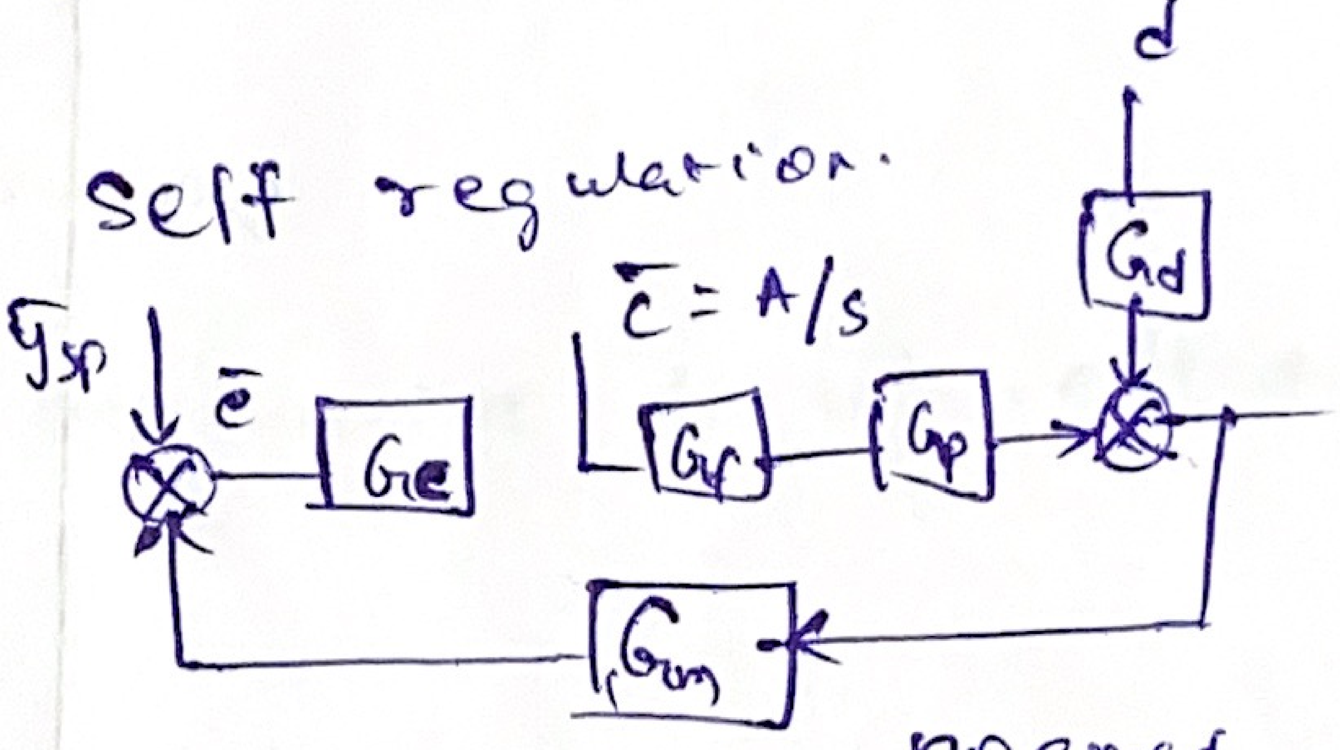
i) Reaction curve Technique (open loop)
(only with self regulation)

ii) Closed loop technique (Continuous cycling method)
(without self regulation).

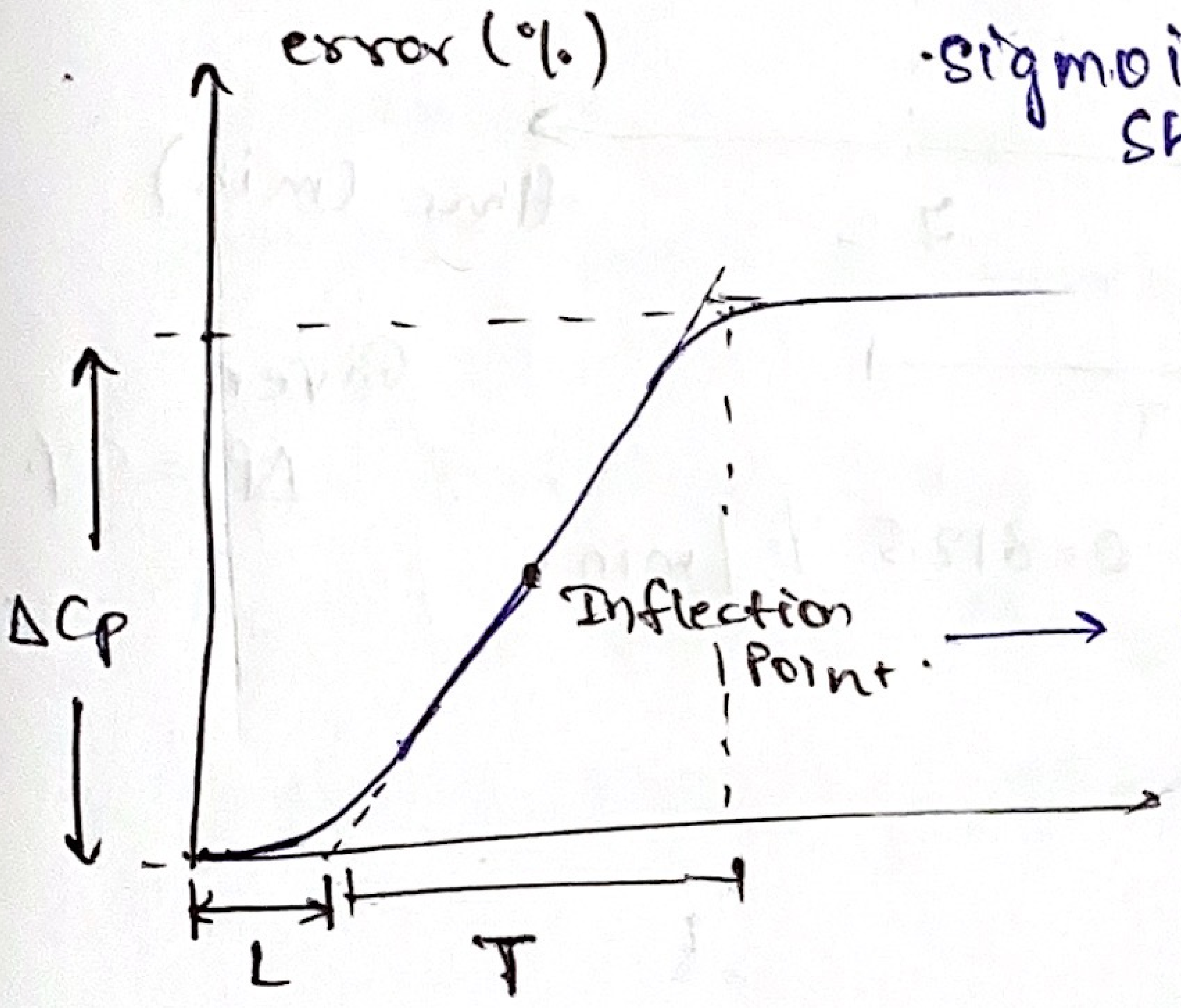
iii) Closed loop (Damped oscillation method).

i) Reaction curve.

Self regulation.



opened control loop



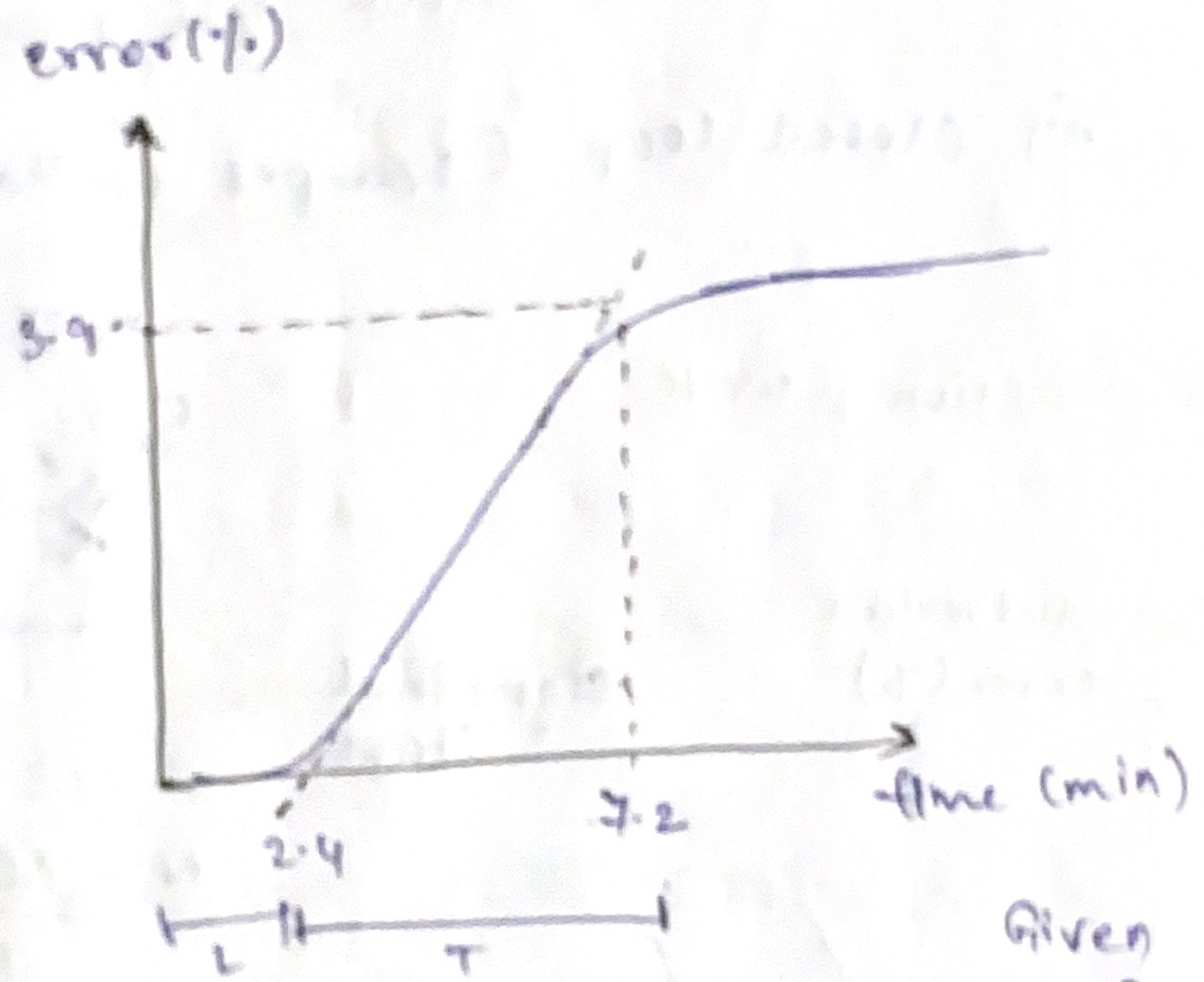
sigmoidal shape.

$N = \frac{\Delta C_p}{T}$ N = reaction rate in %/min.

Inflection Point. → the point where slope stops increasing & begins to decrease.

Zeigler - Nicholas	Cohen-coon
P mode	cohen coon
$k_p = \frac{\Delta P}{NL}$	$k_p = \frac{\Delta P}{NL}\left[1 + \frac{NL}{3\Delta C_p}\right]$
PI	
$k_p = 0.9\frac{\Delta P}{NL}$	$k_p = \frac{\Delta P}{NL}\left[0.9 + \frac{1}{12}R\right]$, $R = \frac{NL}{\Delta C_p}$ (lag ratio)
$T_I = 3.3L$	$T_i = \left[\frac{30+3R}{9+20R}\right]L$
PID	
$k_p = 1.2\frac{\Delta P}{NL}$	$k_p = \frac{\Delta P}{NL}\left[1.33 + \frac{1}{4}R\right]$
$T_I = 2L$	$T_I = \left[\frac{32+6R}{13+8R}\right]L$
$T_D = 0.5L$	$T_D = \left[\frac{4}{11+2R}\right]L$

Q. A transient Disturbance test is run on a process loop. The result of a 9% controlling variable change give a process reaction graph. Find the settings for 3-mode action



Given $\Delta P = 9\%$

Sol. $N = \frac{\Delta C_p}{T} = \frac{3.9\%}{7.2 - 2.4} = 0.8125\ \%/min$

$k_p = 1.2 \frac{\Delta P}{NL} = 5.54$

$T_I = 2L = 4.8$ min.

$T_D = 0.5L = 1.2$ min

$R = \frac{NL}{\Delta C_p} = 0.5$

$k_p = 6.72$

$T_I = 4.94$ min

$T_D = 0.8$ min

closed loop method. (Ultimate cycle method).
(without self regulation).

Adjusting a closed loop until steady oscillations occur.

Controller settings are based on the conditions that generate cycling.

Steps :-

Reduce any integral & derivative to min. effect.

$T_d = 0 \quad T_i = \infty$

Gradually increase the prop gain while providing periodic small disturbances to the process.

K_c - Critical gain at which the dynamic variable just begins to exhibit steady cycling, that is oscillations about set point.

Note the critical time period, T_c of these oscillations (in min)

P mode

$k_p = 0.5 K_c$

PI

$k_p = 0.45 K_c$

$t_i = T_c / 1.2$

for quarter amplitude make $T_I = T_c$ & adjust gain to obtain quarter response.

PID mode

$k_p = 0.6 K_c$

$t_i = T_c / 2$

$T_D = T_c / 8$

for quarter ampli

$T_i = T_c / 1.5$

$T_D = T_c / 6$

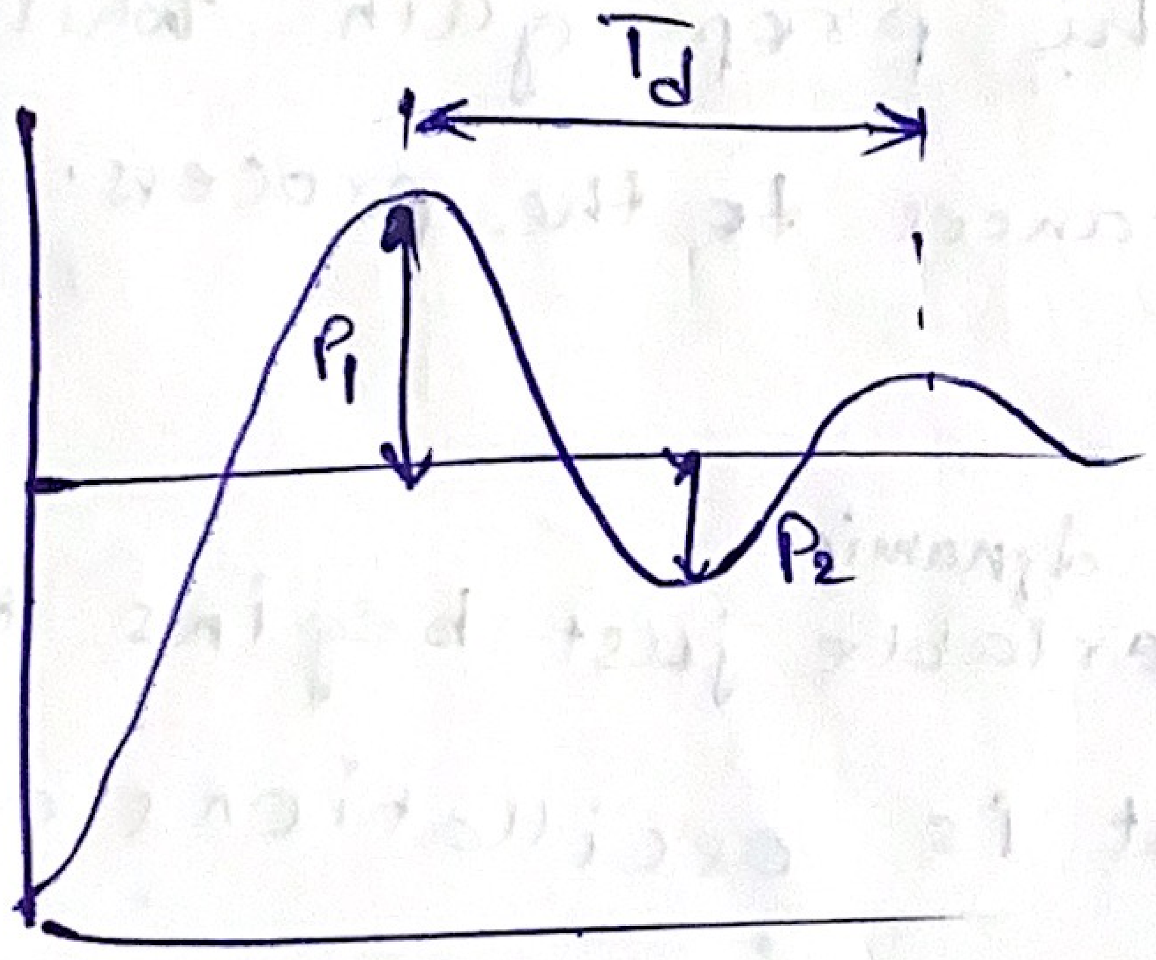
Damped oscillation methon.

For plants that do not allow to undergo sustained oscillation

Initially, closed loop system is operated with low gain P controller with $T_D = 0$ $T_i = \infty$

Gain is increased slowly to get a decay ratio of $1/4$.

Under this condition, the period of damped oscillation T_d is also noded & K_d be the prop. gain setting for obtaining $1/4$ decay ratio.



$T_i = T_d / 1.5$

$T_D = T_d / 6$

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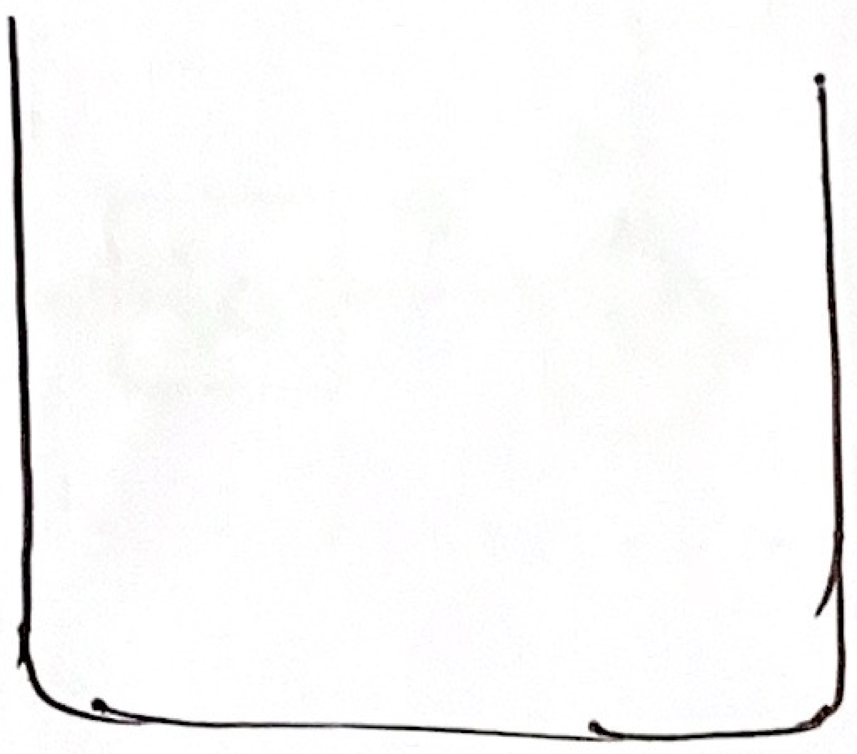
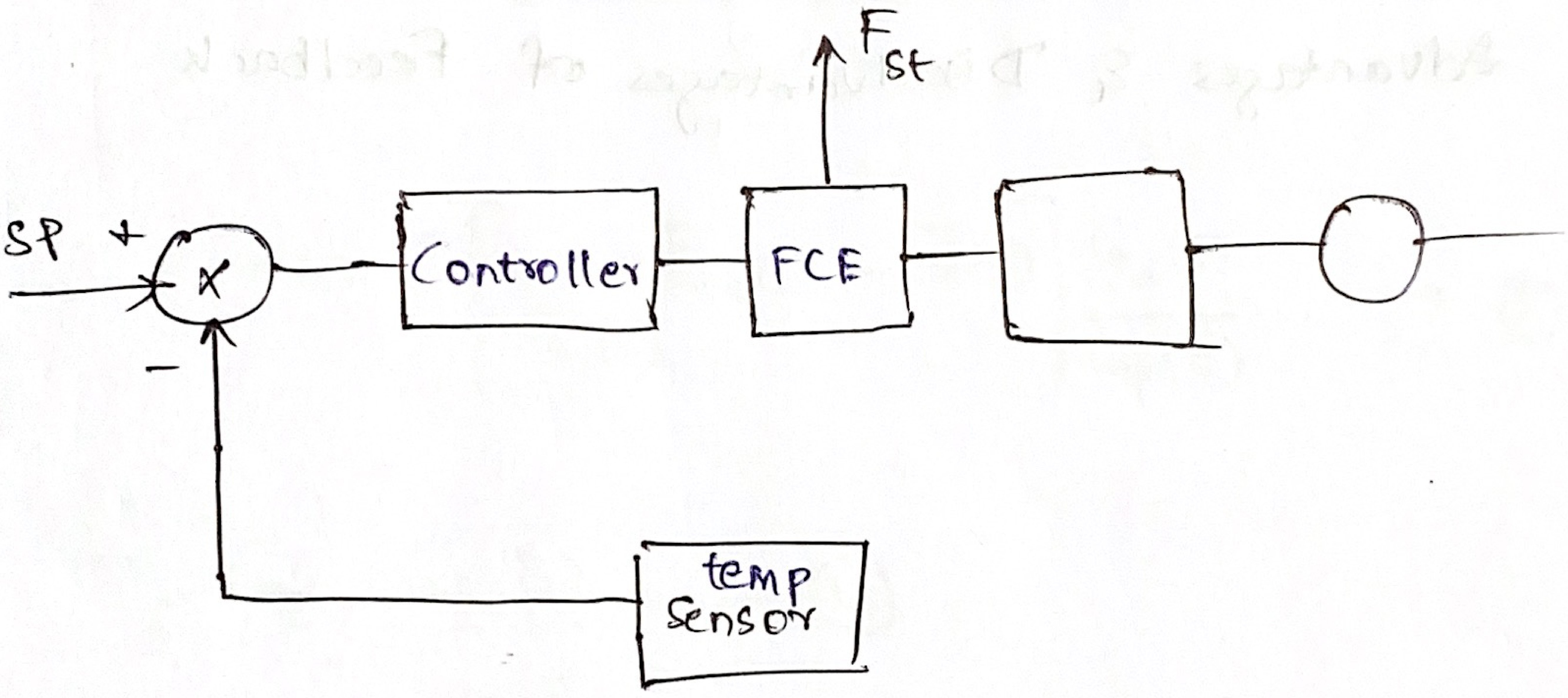
Advanced Controllers.

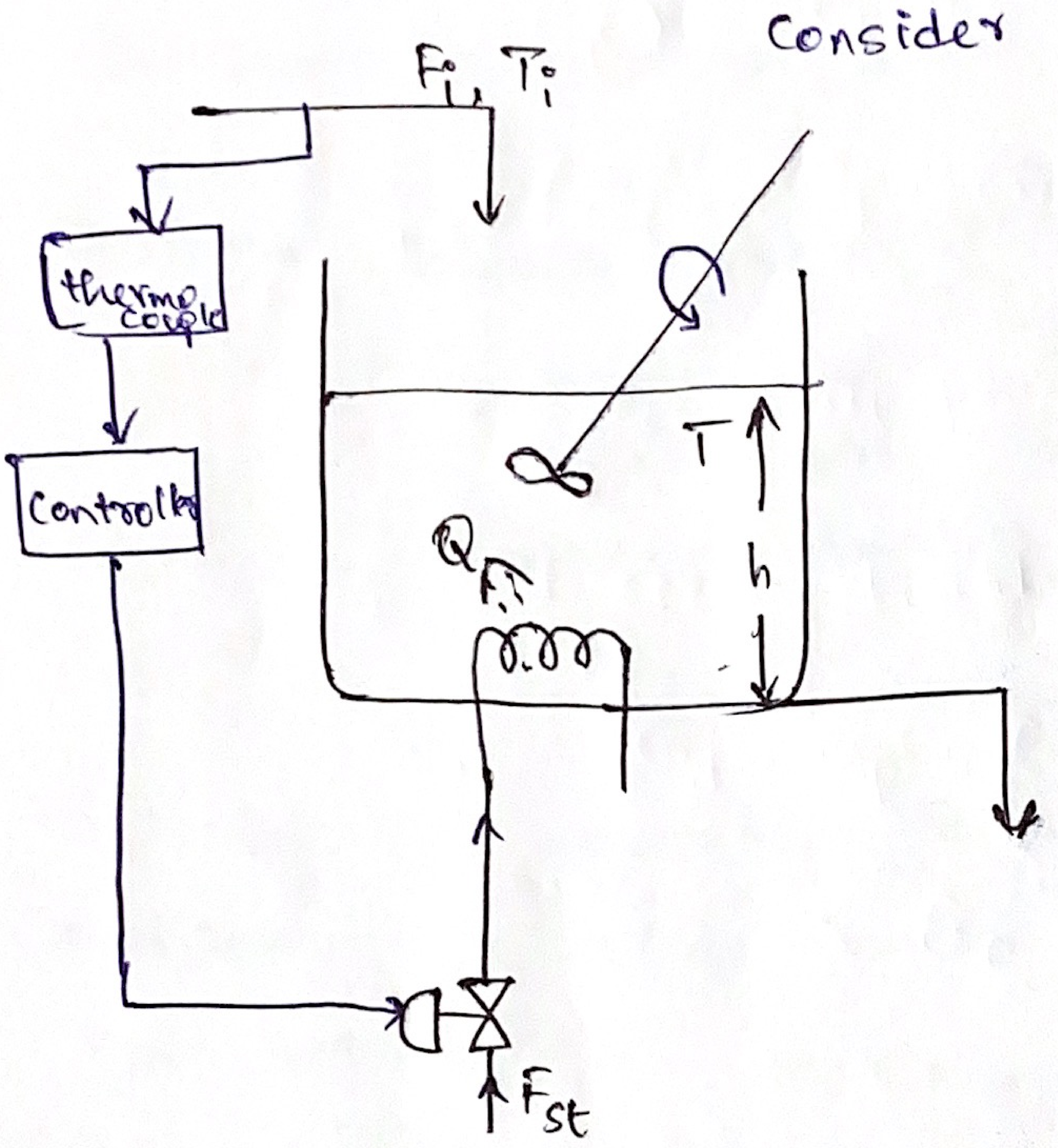
Feed Forward Control





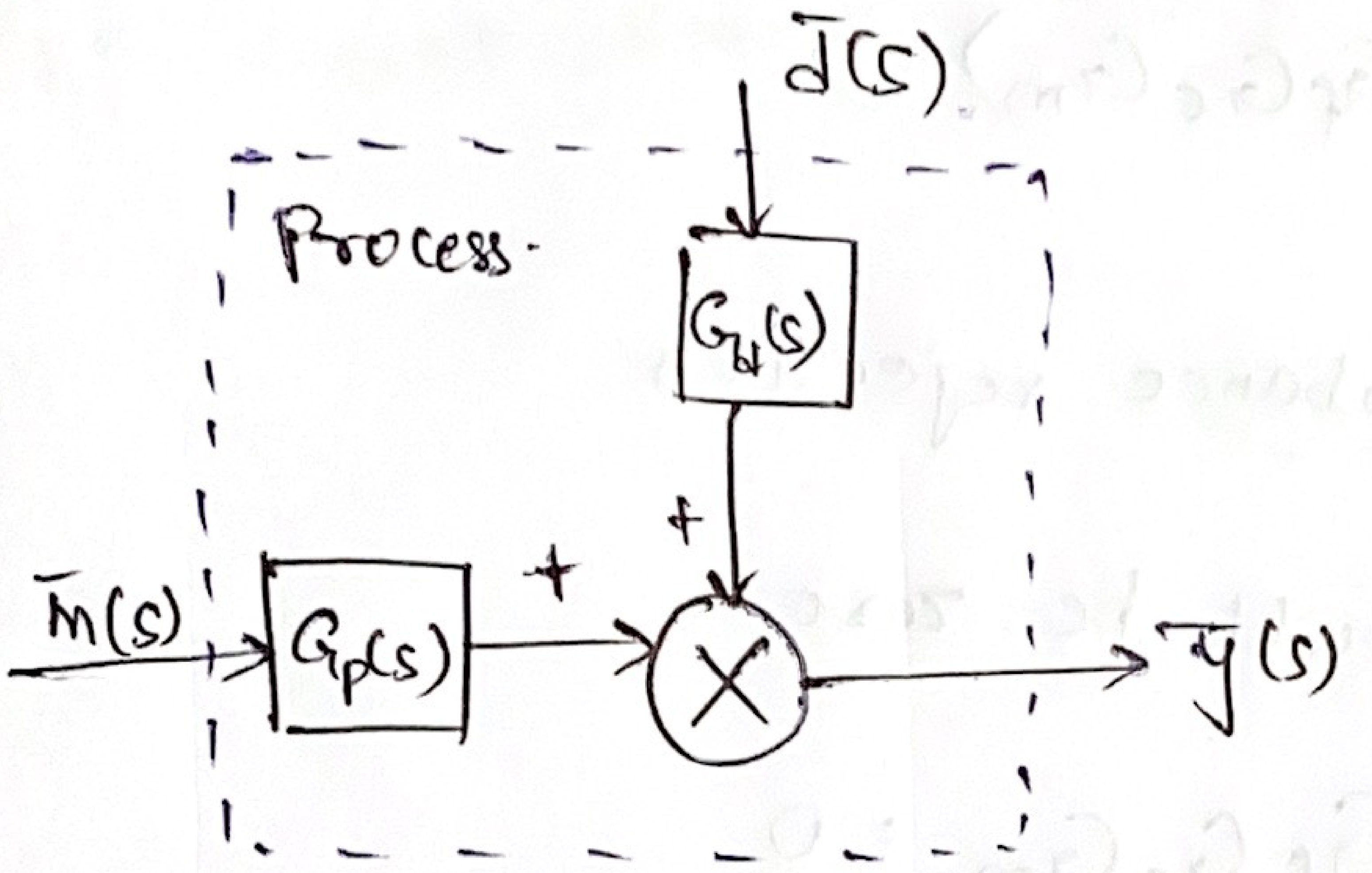
feed for ward loop.

Consider F_i to be constant.



Advantages & Disadvantages of Feedback

Design Procedures.



$\bar{y}(s) = \bar{m}(s)\,G_p(s) + \bar{d}(s)G_d(s)$

① Consider the o/p has reached set point $\bar{y}_{sp}(s)$.

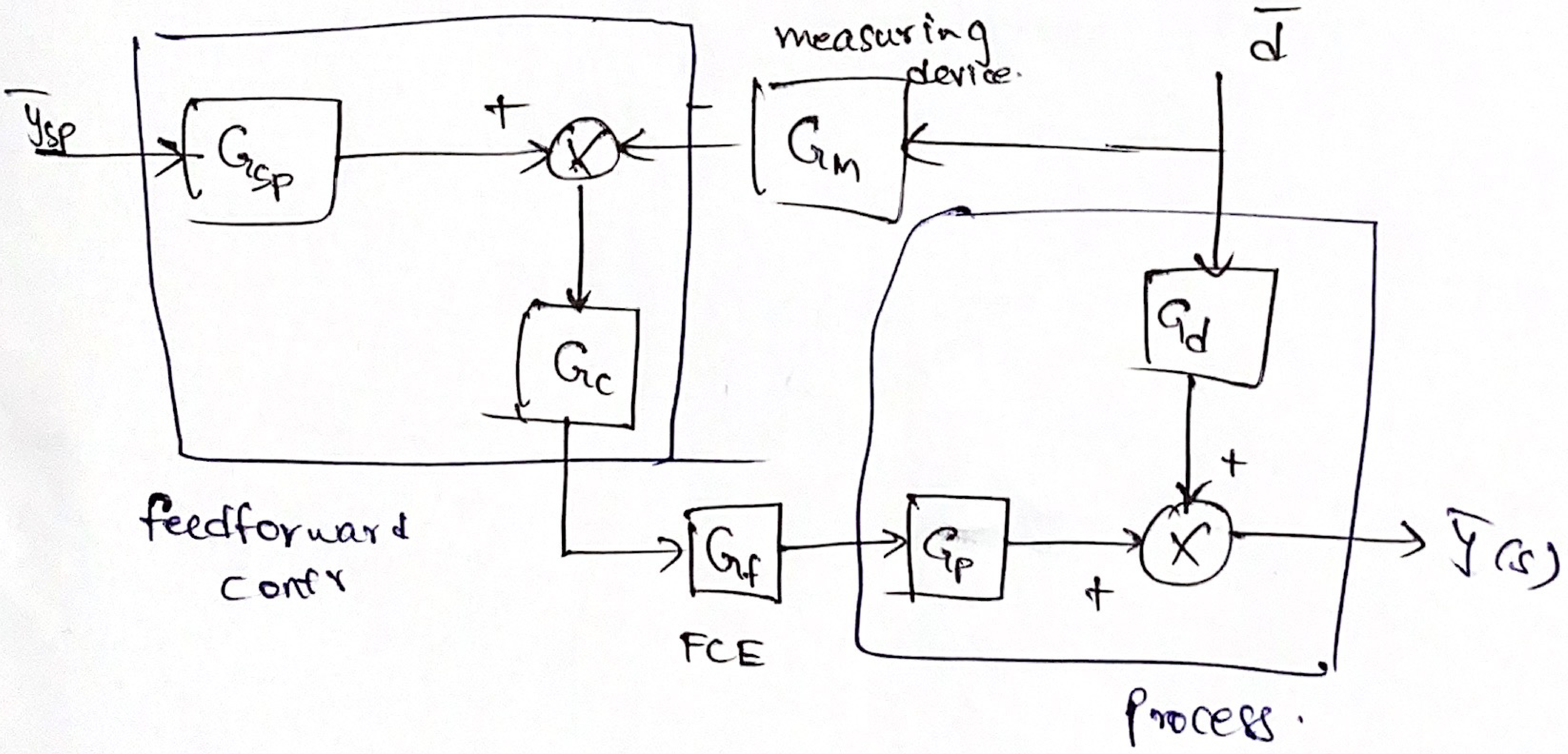
So, $\bar{y}_{sp}(s) = \bar{m}(s)\,G_p(s) + \bar{d}(s)\cdot G_d(s) \longrightarrow ②$

$$\Rightarrow \bar{m}(s) = \frac{\bar{y}_{sp}(s) - G_d(s)\cdot\bar{d}(s)}{G_p(s)}$$

$$\bar{m}(s) = \left[\frac{1}{G_d(s)}\bar{y}_{sp}(s) - \bar{d}(s)\right]\frac{G_d(s)}{G_p(s)} \longrightarrow ③$$

$$G_c = \frac{G_d(s)}{G_p(s)} \longrightarrow ④$$

$$G_{sp} = \frac{1}{G_d(s)}$$



2/11/22

Design

$$\bar{y}(s) = (G_p G_f G_c G_{sp})\, \bar{y}_{sp} + \bar{d}\, G_d(s) - G_p G_f G_c G_m \bar{d}$$

$$\bar{y}(s) = (G_p G_f G_c G_{sp})\bar{y}_{sp} + \bar{d}\,(G_d - G_p G_f G_c G_m)$$

→ To make disturbance rejection

i.e, $\bar{d}$ coeff. should be zero.

so, $G_d - G_p G_f G_c G_m = 0$

$$\Rightarrow G_c = \frac{G_d}{G_p G_f G_m}.$$

→ for setpoint tracking

Coeff of $\bar{y}_{sp} = 1$

So, $G_p G_f G_c G_{sp} = 1$

$$G_{sp} = \frac{1}{G_p G_f G_c} = \frac{1}{\cancel{G_p G_f}\left(\frac{\cancel{G_p G_f} G_m}{G_D}\right)}$$

$$\Rightarrow G_{sp} = \frac{G_m}{G_D} \quad //$$

Example.

Objective :- To maintain temp T at T_{sp}. Assume

F_i doesn't change $F_i = F$

Transient energy balance eq.

$$V\rho C_p \frac{dT}{dt} = F\rho C_p (T_i - T) + Q$$

$$A \cdot \frac{dh}{dt} = F_i - F$$

$$Ah \frac{dT}{dt} = F_i (T_i - T) + \frac{Q}{\rho C_p}$$

where A - area of tank

h - height of liquid

ρ - Density of liquid

C_p - liquid's heat capacitance

Q - Heat input

i) Steady state feed forward Controller.

$$0 = F_i (T_i - T) + \frac{Q}{\rho C_p}$$

$$T = T_i + \frac{Q}{F_i \rho C_p}$$

Design eq, is the eq that relates controlled variable to the manipulated variable.

$$\Rightarrow Q = F_i \rho C_p (T_{sp} - T_i)$$