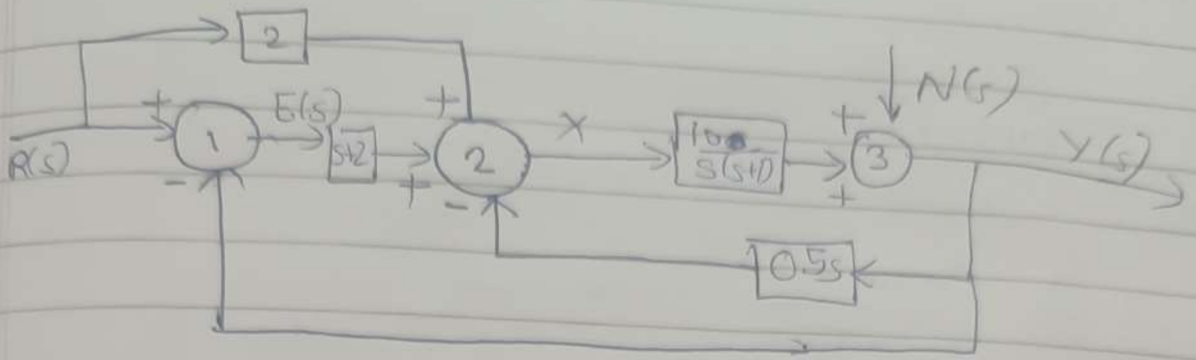
~~6a)~~

SPACE STATION : Controls and communication



At 1 (Summing point 1)

$+R - Y = E.$

At 2 (Summing point)

$$2R + (s+2)E - \frac{sY}{2} = X.$$

Passing a block $\boxed{2}$ Passing $\boxed{s+2}$ Passing $\frac{s}{2}$ from take off point Y

At 3 (Summing point)

$$\frac{X(100)}{s(s+1)} + N = Y.$$

(a.) $N=0$.

$$\therefore X = \frac{Ys(s+1)}{10}.$$

Putting in ②,

$$2R + (s+2)E - \frac{sY}{2} = \frac{Ys(s+1)}{10}$$

$$\Rightarrow E = \frac{\frac{Ys(s+1)}{10} + \frac{sY}{2} - 2R}{s+2}$$

Putting in ①

$$R - Y = \frac{Ys(s+1) + 5sY - 20R}{10(s+2)}$$

$$R + \frac{2R}{s+2} = Y\left[\frac{s^2+s+5s+10s+20}{10(s+2)}\right]$$

$$R\frac{(s+4)}{\cancel{s+2}} = \frac{Y(s^2+16s+20)}{10\cancel{(s+2)}}$$

$$\Rightarrow \boxed{\frac{Y}{R} = \frac{(s+4)10}{s^2+16s+20}}.$$

(b) $\left.\frac{Y}{E}\right|_{N=0}$

$$\frac{Y}{R} = \frac{10(s+4)}{s^2+16s+20}$$

$$\frac{Y}{Y+E} = \frac{10(s+4)}{s^2+16s+20}$$

$$\Rightarrow 1+\frac{E}{Y} = \frac{s^2+16s+20}{10s+40}$$

$$\Rightarrow \frac{E}{Y} = \frac{s^2+6s-20}{10s+40}$$

$$\Rightarrow \frac{Y}{E} = \boxed{\frac{10(s+4)}{s^2+6s-20}}.$$

(c) $\left.\frac{Y}{N}\right|_{R=0}$.

(1) becomes $Y = -E$.

(2) becomes $\cancel{0}(s+2)E - \frac{sY}{2} = X$

$$\therefore X = -(s+2)Y - \frac{sY}{2}$$

$$= -\left(\frac{3s}{2}+2\right)Y$$

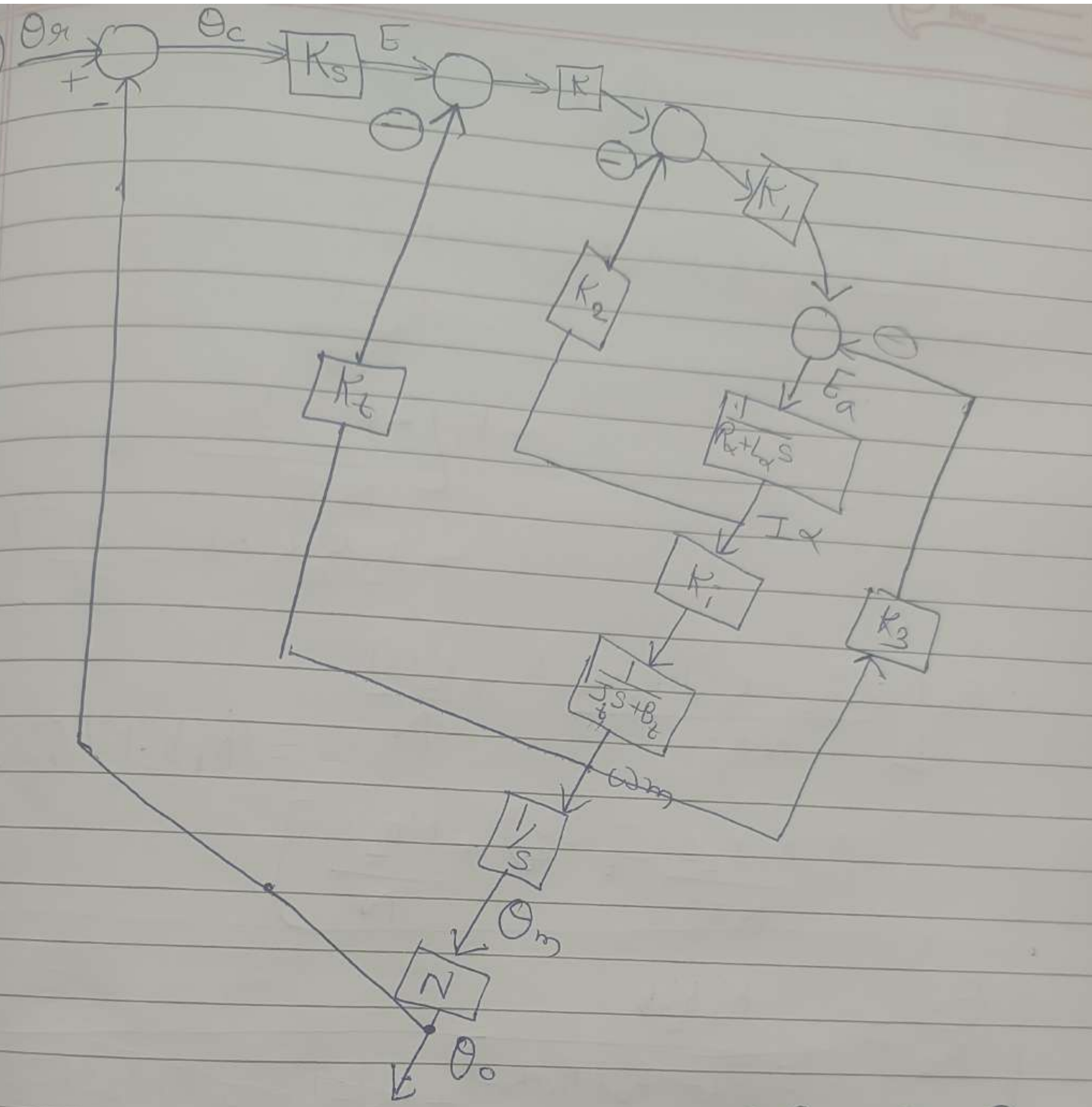
$\therefore$ 3 becomes

$$\frac{-\left(\frac{3s}{2}+2\right)Y(10)}{s(s+1)} \cancel{0} + N = Y$$

$$\Rightarrow \frac{N}{Y} = 1 + \frac{5(3s+4)}{2s(s+1)}$$

$$= \frac{2s^2+2s+15s+20}{2s(s+1)} = \boxed{\frac{2s^2+17s+20}{2s^2+2s}}.$$

2.



$\theta_e = \theta_r - \theta_o \Rightarrow \cancel{\theta \; 1 = \frac{\theta_e}{\theta_r} \quad 1 - \frac{\theta_o}{\theta_r}} \Rightarrow \theta_o = \theta_r - \theta_e.$

$\left[(K_s\theta_e - K_t\omega_m)K - K_2 I_\alpha\right]K_1 - K_3\omega_m = E_\alpha.$

$\frac{E_\alpha}{R_\alpha + L_\alpha s} = I_\alpha$

$\frac{\omega_m}{s} = \theta_m \qquad \omega_m = s\theta_m = \frac{s\theta_o}{N}.$

$I_\alpha K_i = T_m.$

$N\theta_m = \theta_o \qquad T_m = \frac{s\theta_o}{N}(J_t s + B_t)$

$\frac{T_m}{J_t s + B_t} = \omega_m.$

$E_\alpha = I_\alpha(R_\alpha + L_\alpha s). \qquad I_\alpha = \frac{s\theta_o}{N K_i}(J_t s + B_t).$

$$E_\alpha = \frac{s\theta_o}{NK_i}(J_t s + B_t)(R_\alpha + L_\alpha s)$$

$$\therefore \frac{s\theta_o}{NK_i}(J_t s + B_t)(R_\alpha + L_\alpha s) = E_\alpha.$$

$$= -K_s \frac{s\theta_o}{N}$$

$$+ K_1\left[-\frac{K_2 s\theta_o}{NK_i}(J_t s + B_t) + K_s\theta_e K - KK_t \frac{s\theta_o}{N}\right]$$

$$\therefore \theta_o\left[\frac{s(J_t s + B_t)(R_\alpha + L_\alpha s)}{NK_i} + \frac{K_s(s)}{N} + \frac{K_1 K_2 s(J_t s + B_t)}{NK_i} + \frac{KK_t s}{N}\right] = (K_1 K_s K)\theta_e.$$

$$\boxed{\frac{\theta_o}{\theta_e} = \frac{K_1 K_s K}{\frac{s(J_t s + B_t)(R_\alpha + L_\alpha s)}{NK_i} + \frac{K_s(s)}{N} + \frac{K_1 K_2 s(J_t s + B_t)}{NK_i} + \frac{KK_t s}{N}} = \alpha.}$$

Now, $\dfrac{\theta_o}{\theta_r - \theta_o} = \dfrac{\theta_o}{\theta_e}$

$$\Rightarrow \frac{1}{\frac{\theta_r}{\theta_o} - 1} = \frac{\theta_o}{\theta_e}. \qquad \therefore \frac{\theta_o}{\theta_r} = \frac{1}{\frac{\theta_e}{\theta_o} + 1}$$

$$\Rightarrow \frac{\theta_r}{\theta_o} = \frac{\theta_e}{\theta_o} + 1 \qquad = \frac{\theta_o}{\theta_e + \theta_o}.$$

$$\therefore \frac{\theta_o}{\theta_r} = \frac{1}{\alpha + 1}$$

where $\alpha = \frac{\theta_o}{\theta_e}$.