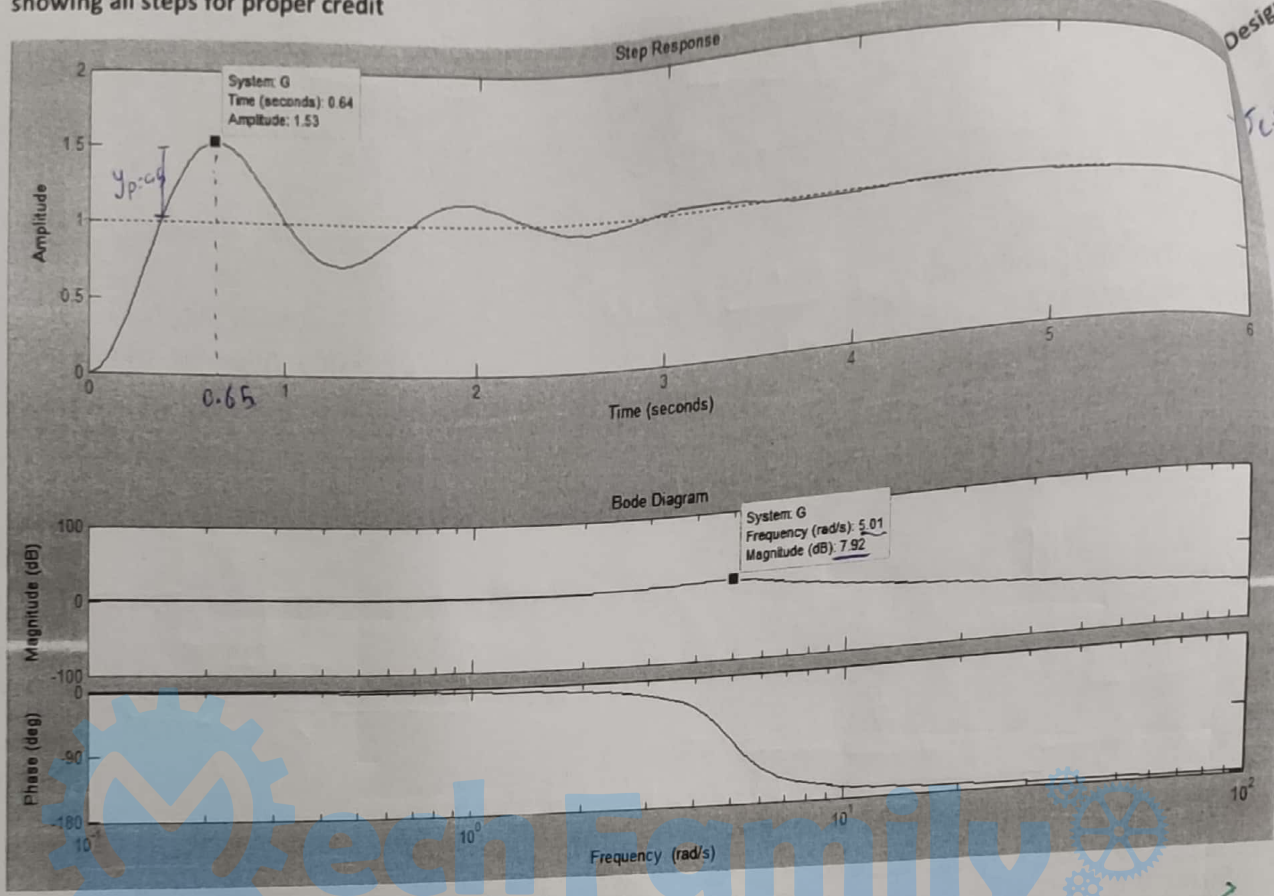
## Problem-1 (6pts)

Given the following system response in time and frequency domain, identify (find) the system's transfer function showing all steps for proper credit




1) over shoot $= \dfrac{y_p - y_{ss}}{y_{ss}}\% = \dfrac{1.53-1}{1} = 0.53\% \Rightarrow 0.53 = e^{\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right)}\% \Rightarrow \boxed{\zeta = 0.198}$ Under damped

2) $t_p = \dfrac{\pi}{w_d} \Rightarrow 0.65 = \dfrac{\pi}{w_d} \Rightarrow \boxed{w_d = 4.833 \text{ rad/s}} \Rightarrow w_n\sqrt{1-\zeta^2} = 4.833$ , $\boxed{w_n = 4.93 \text{ rad/s}}$

$$T.F = \frac{w_n^2}{s^2 + 2\zeta w_n s + w_n^2} = \frac{24.3}{s^2 + 1.95s + 24.3} + 2.488$$

$$\boxed{T.F = \frac{24.3}{s^2 + 1.95s + 24.3} + 2.488}$$

$20\log(X) = 7.92$

$X = 2.488$

2.5

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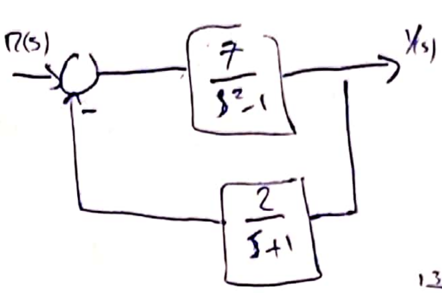
**Problem-II (8pts)**

Design a controller to stabilize the system $G(S) = \frac{7}{s^2-1}$ with feedback $H(S) = \frac{2}{S+1}$

$$G_{c.l} = \frac{\frac{7}{s^2-1}}{1 + \frac{7}{(s^2-1)(s+1)} * 2} = \boxed{\frac{7(s+1)}{s^3+s^2-s+13}}$$



*using RH method :-

| | | |
|---|---|---|
| $s^3$ | 1 | -1 |
| $s^2$ | 1 | 13 |
| $s^1$ | $h_1 = -24$ | 0 |
| $s^0$ | 13 | |

$$h_1 = \frac{\begin{vmatrix} 13 + 1 \end{vmatrix}}{-1} = -24$$

* since we have a change in sign, the system is unstable.

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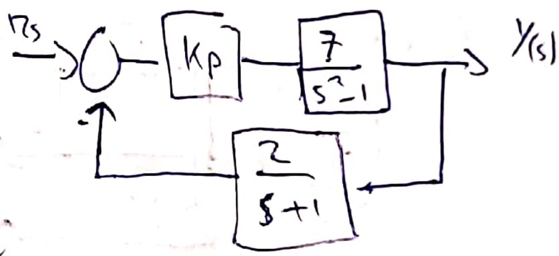
* by using ~~Kp~~ P controller



$$G_{c.l} = \frac{\frac{7Kp}{s^2-1}}{1 + \frac{(7Kp)(2)}{(s^2-1)(s+1)}} = \frac{7Kp(s+1)}{s^3+s^2-s+14Kp-1}$$

| | | |
|---|---|---|
| $s^3$ | 1 | -1 |
| $s^2$ | 1 | $14Kp-1$ |
| $s^1$ | $h_1$ | 0 |
| $s^0$ | $14Kp-1$ | |

$$h_1 = \frac{14Kp - 1 + 1}{-1} = \boxed{-14Kp}$$

* to stabilize the system $-14Kp > 0$

$$\boxed{Kp < 0}$$

* also $14Kp - 1 > 0$

$$\boxed{Kp > \frac{1}{14}} \Rightarrow \text{so still unstable by Kp}$$

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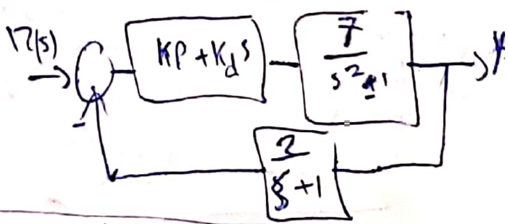
*using PD controller

$$G_{c.l} = \frac{7(Kp+K_ds)(s+1)}{s^3+s^2-s-1+14Kp+14K_ds}$$



| | | |
|---|---|---|
| $s^3$ | 1 | $14K_d - 1$ |
| $s^2$ | 1 | $14Kp - 1$ |
| $s^1$ | $h_1$ | 0 |
| $s^0$ | $14Kp-1$ | |

$$h_1 = \frac{14Kp - \cancel{1} - 14K_d + \cancel{1}}{-1}$$

$$h_1 = 14K_d - 14Kp > 0$$

$$\boxed{K_d > Kp}$$

$\hookrightarrow 14Kp - 1 > 0$

$$\boxed{Kp > \frac{1}{14}}$$

* the system will be stable by using PD controlle

$K_d = (\frac{1}{14}, \infty)$ $\quad$ $Kp = [\frac{1}{14}, \infty)$

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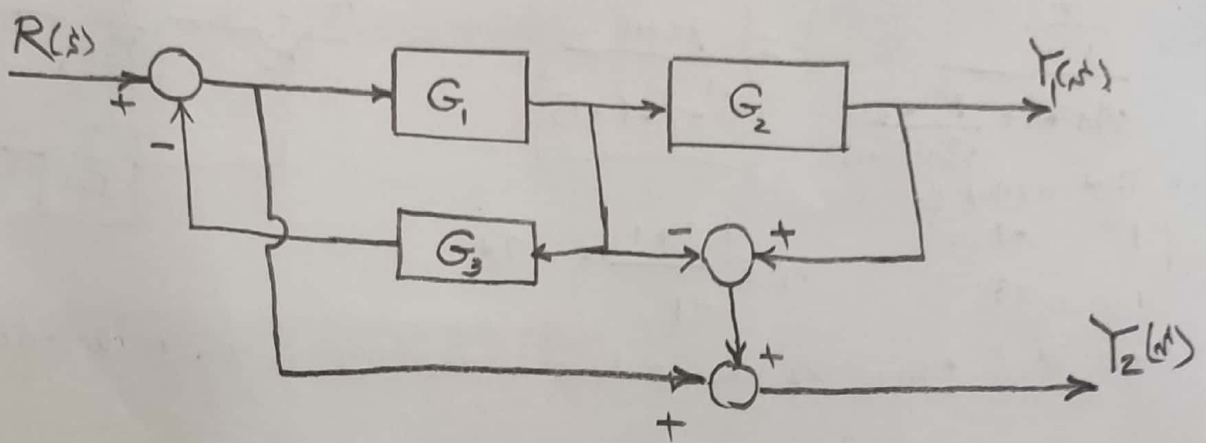
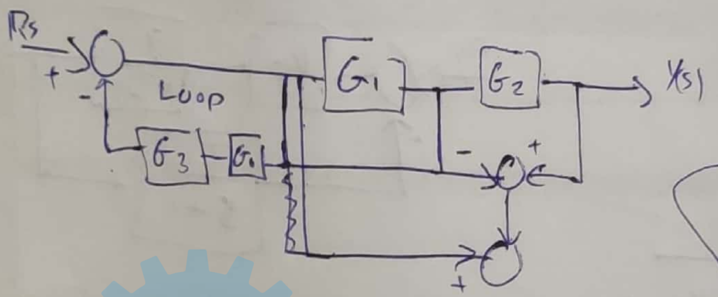
**Problem-III (6pts)**

**Using block diagram reductions find the system's transfer function** $\frac{Y_1(s)}{R(s)}$

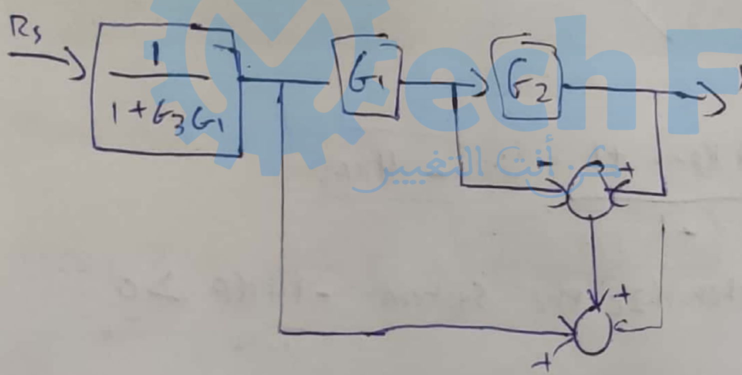



$Y_2(s)=0$

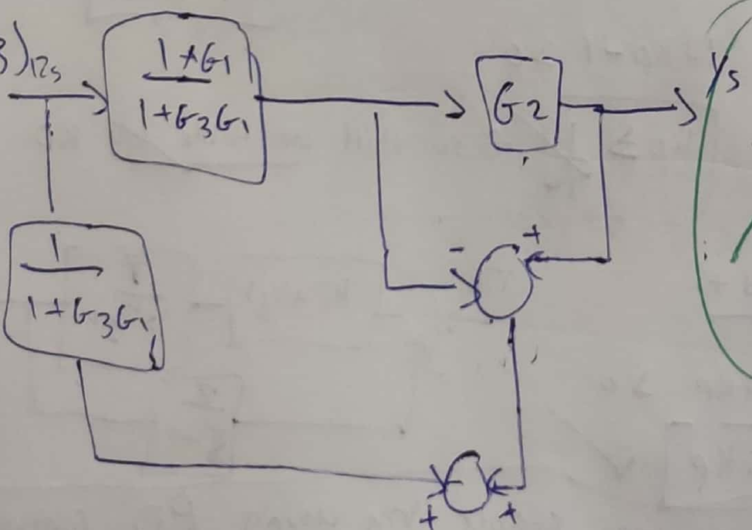
1)



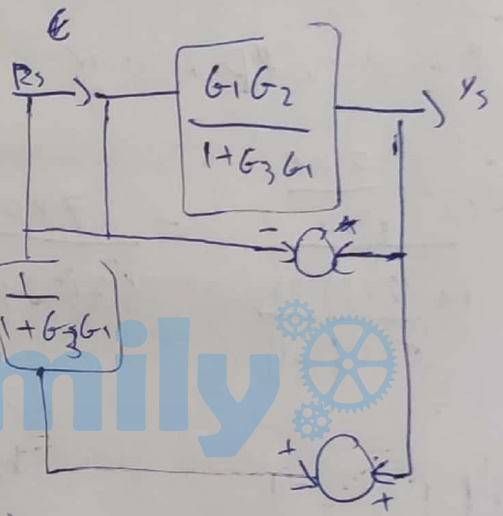

2)



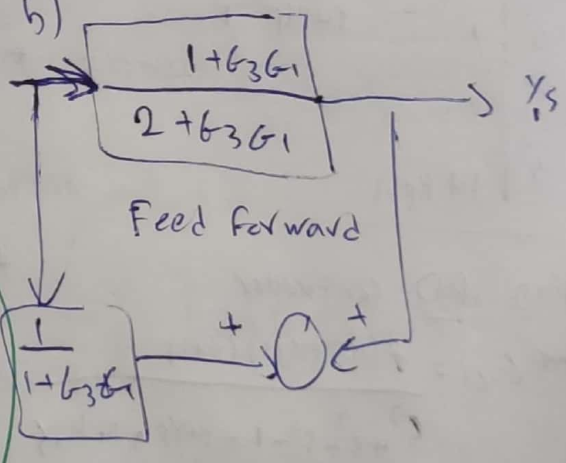

3)




4)




5)




$$\frac{Y_1 s}{R(s)} = \frac{1+G_3G_1}{2+G_3G_1} + \frac{1}{1+G_3G_1}$$