1-

Dynamic equations:

Equation of motion of M1:

M1 X1''= U- k1X1 - F1X1' + K2X2 -K2X1

Transfer equation:

(S^2)M1X1(S) = U(S) - F1SX1(S) - K2X1(S) +K2X2(S) - K1X1(S)

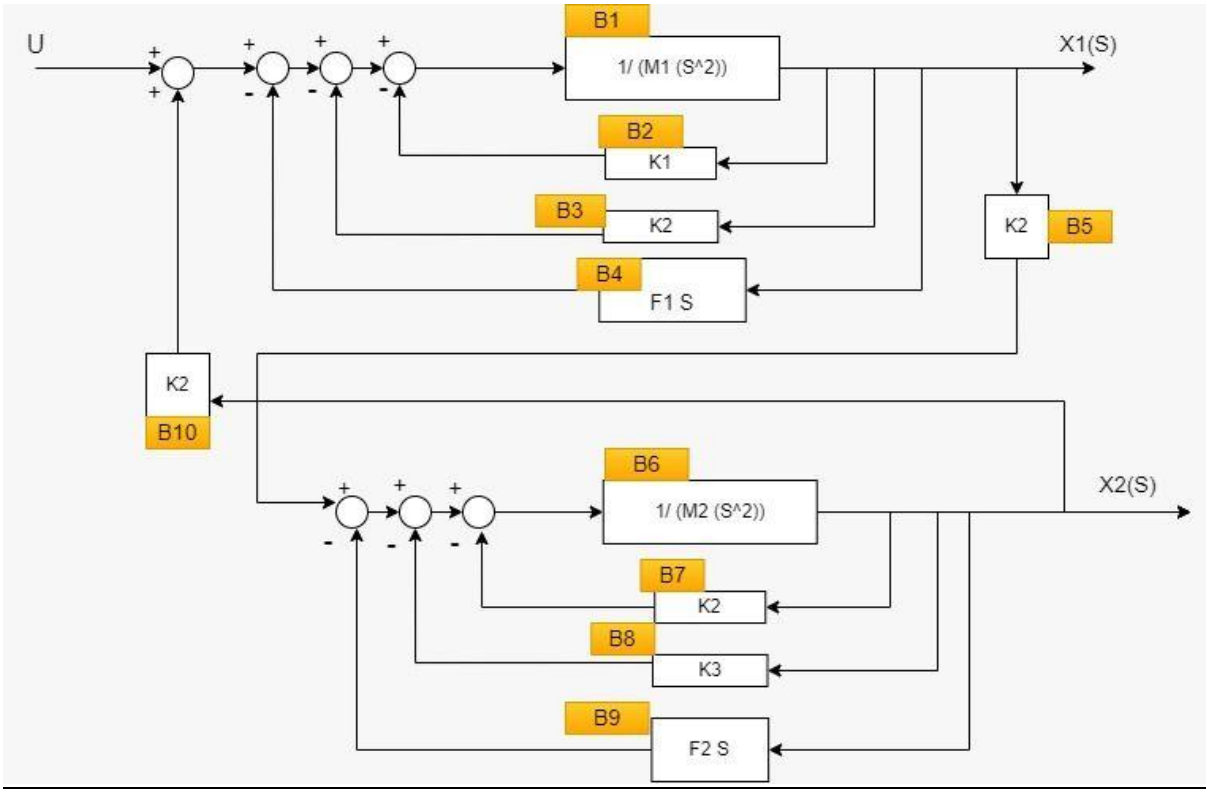
Equation of motion of M2:

M2X2''= K2X1 - F2X2' - K2X2 -K3X2

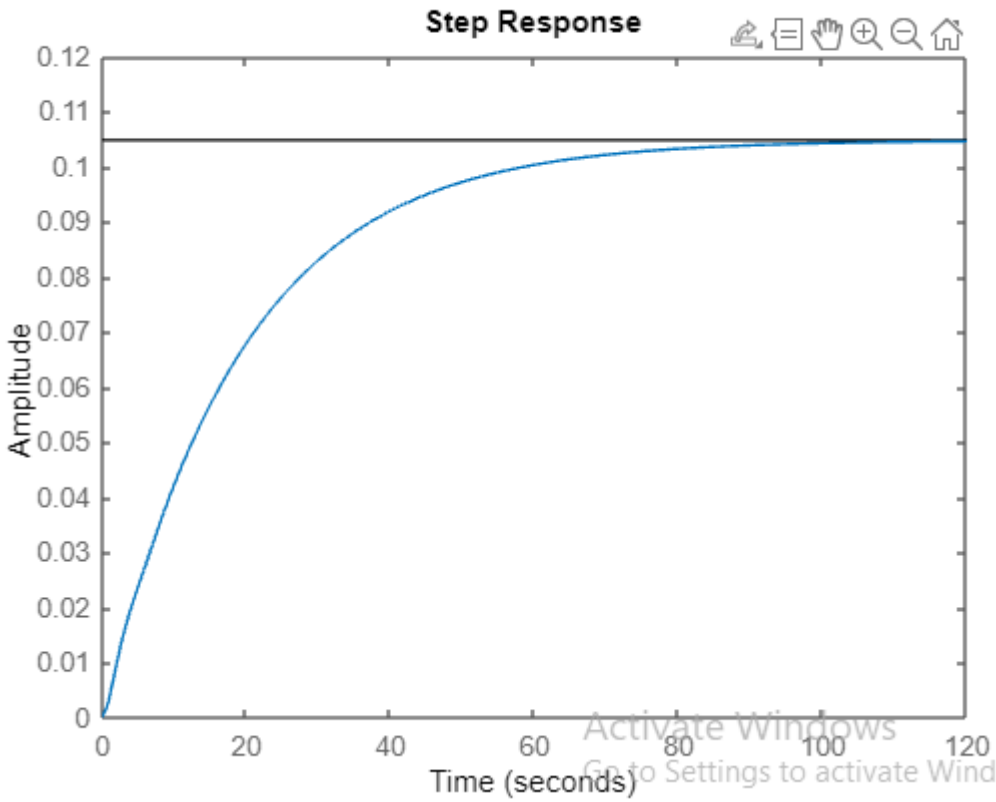
Transfer equation:

(S^2)M2X2(S) = K2X1(S) - F2SX2(S) - K2X2(S) - K3X2(S)

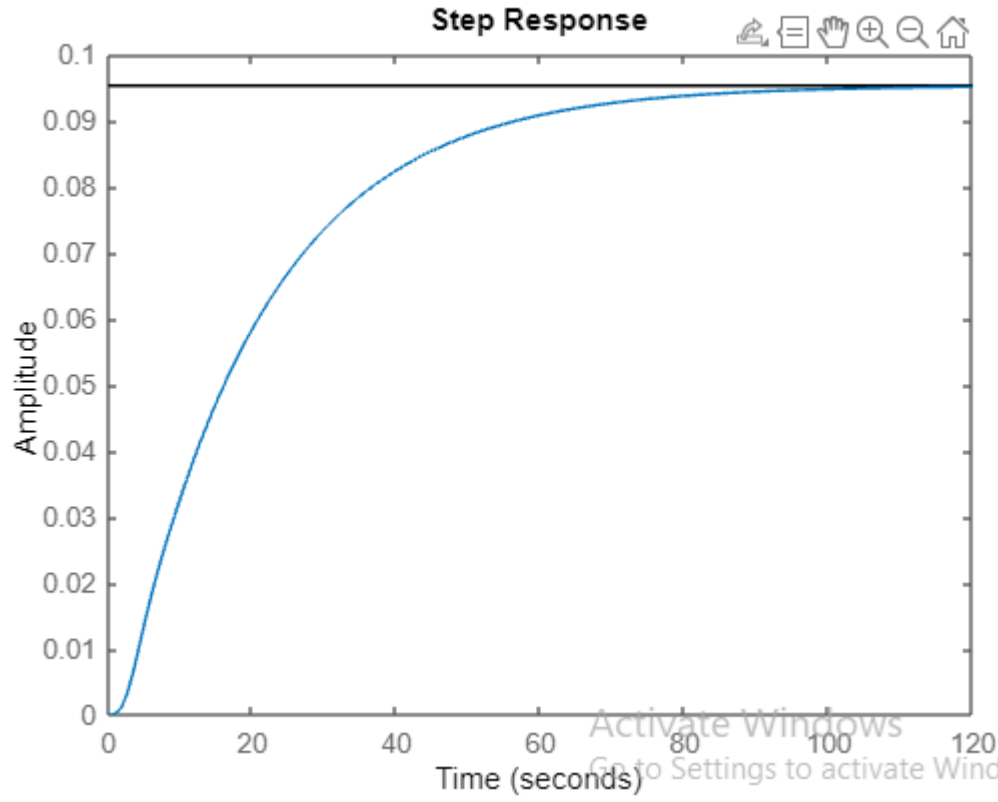
Block diagram:



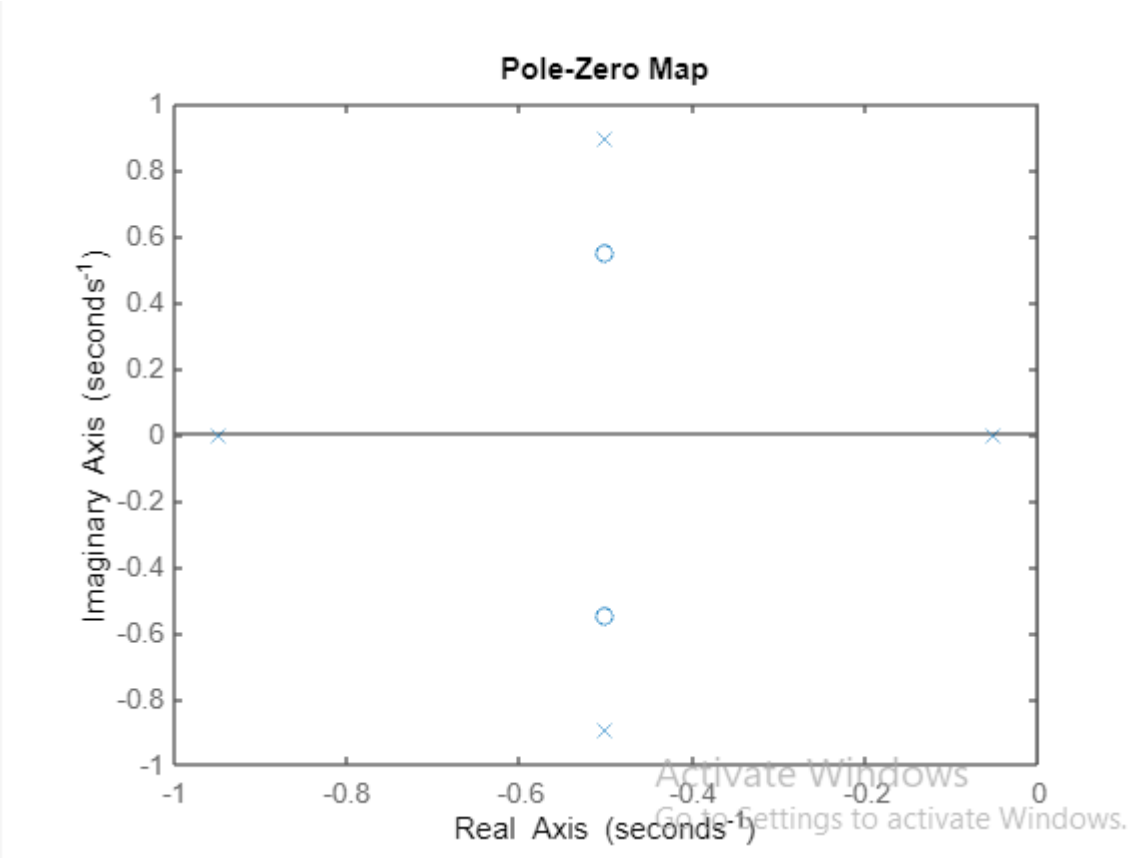
2-X1/U



X2/U

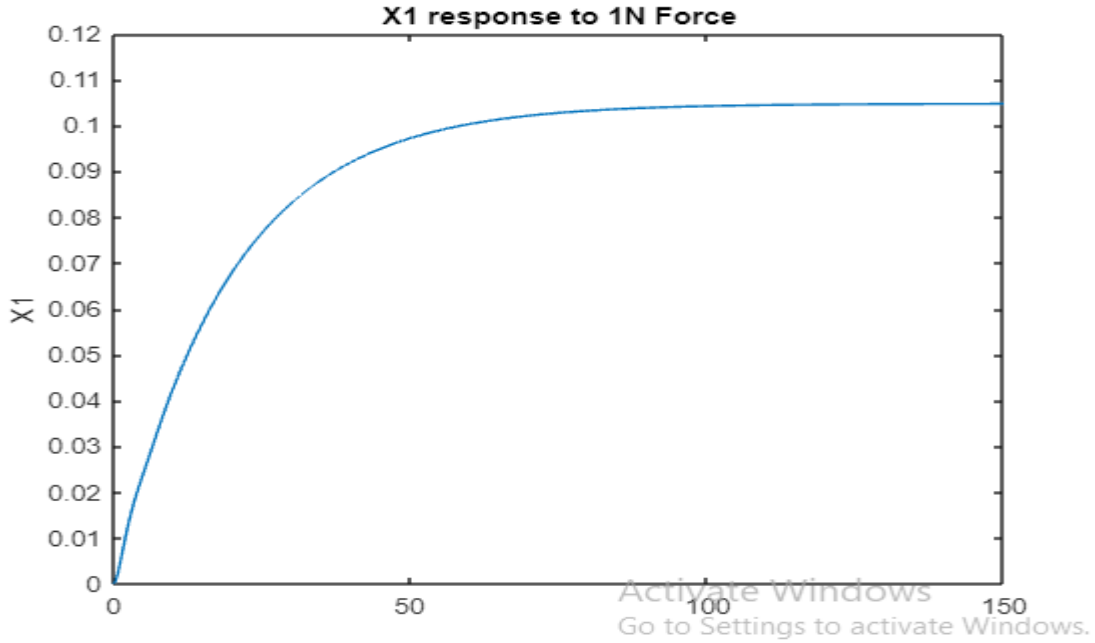


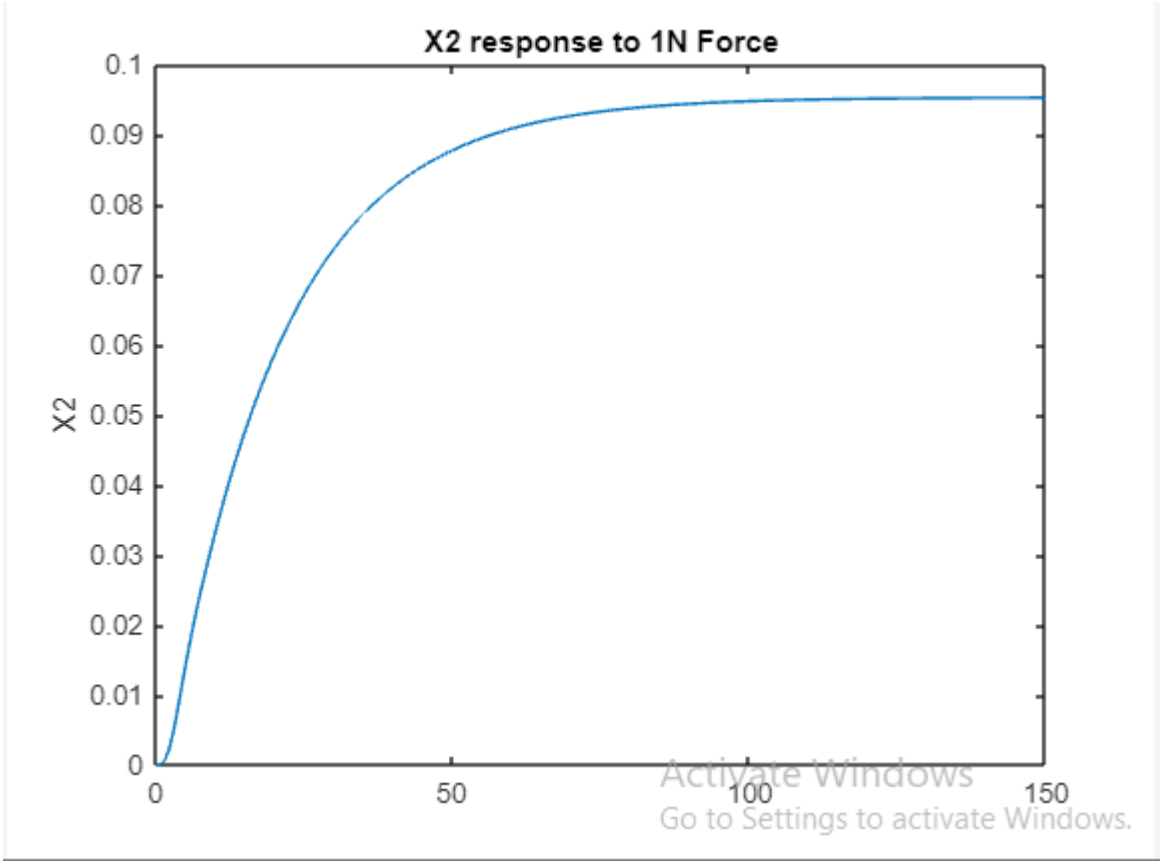
3-X1 is stable as all poles are in the negative half



➔function **`isstable(sys1)`** in Matlab to check stability

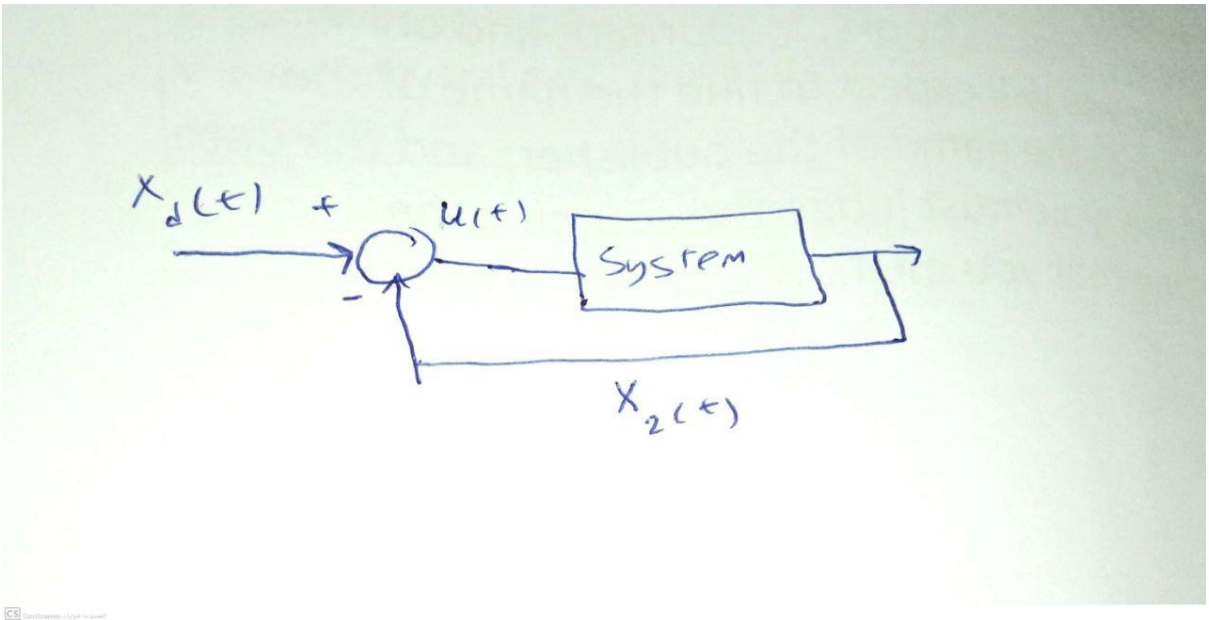
4-



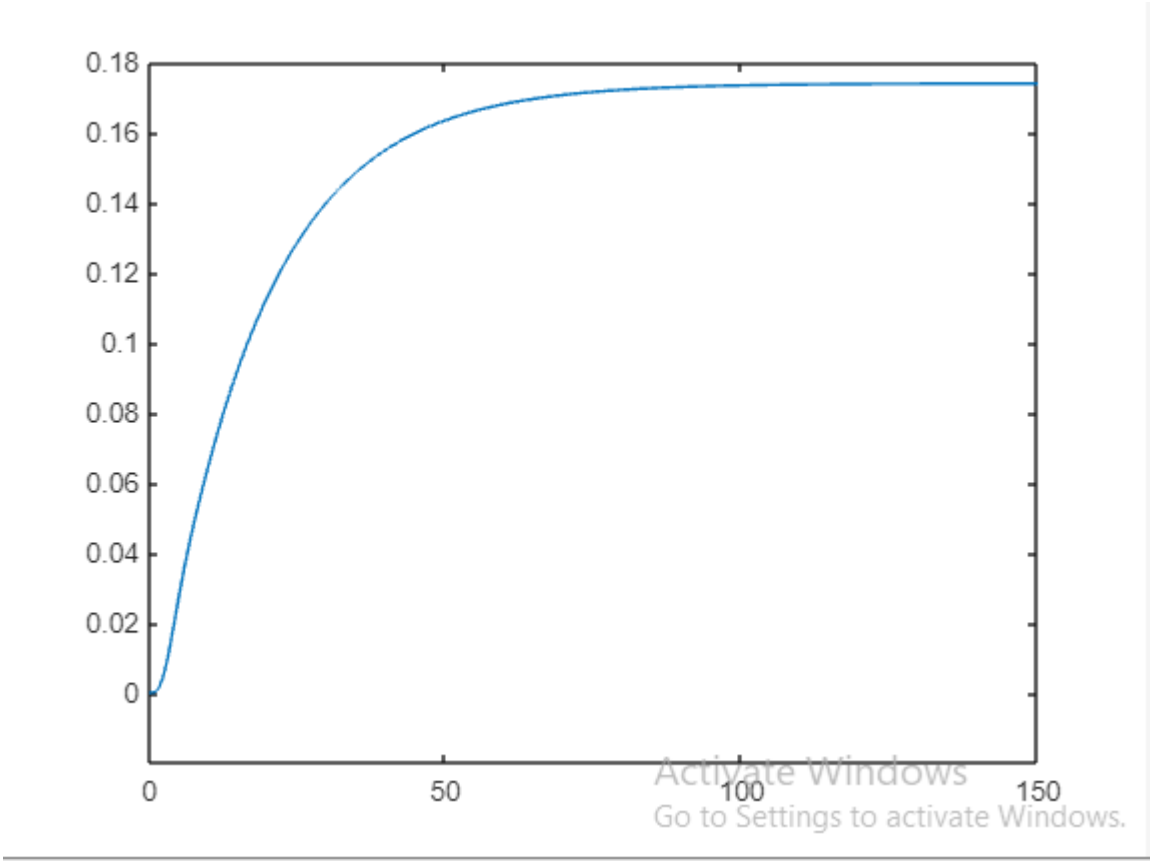



```
Steady state value of X1 is 0.104701
Steady state value of X2 is 0.095150
```

5-



6-



7-

```
Rise time = 37.436246
Peak time = 150.000000
Max peak = 0.173883
Settling time = 68.815786
Steady state error = 1.826117
```

8-

For P =1:

```
Rise time of X2 is 37.436246
Peak time of X2 is 150.000000
Max peak of X2 is 0.173883
Settling time of X2 is 68.815786
Steady state error of X2 is 1.826117
```

For P =10:

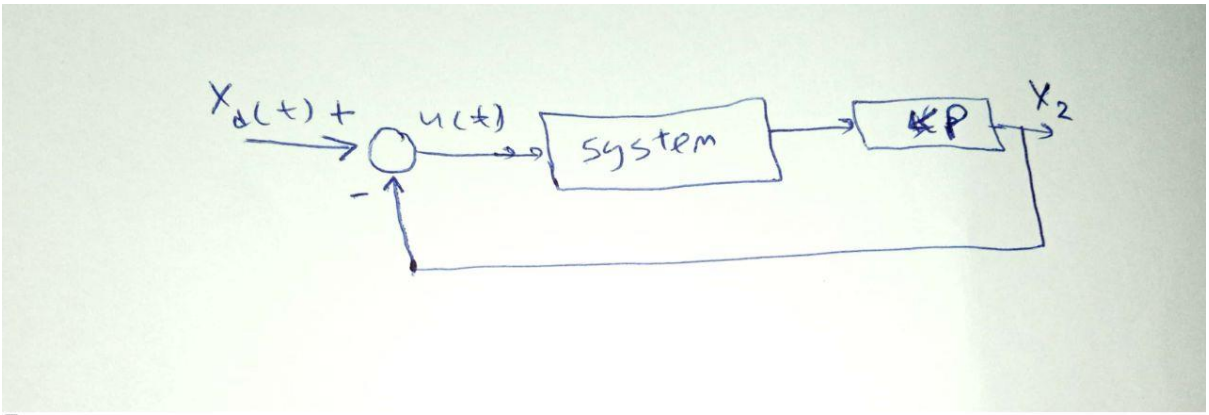
```
Rise time of X2 is 18.846006
Peak time of X2 is 150.000000
Max peak of X2 is 0.975610
Settling time of X2 is 35.781356
Steady state error of X2 is 1.024390
```

For P =100:

Rise time of X2 is 2.216290
Peak time of X2 is 6.300000
Max peak of X2 is 2.683290
Settling time of X2 is 31.014244
Steady state error of X2 is 0.190045

For P =1000:

unstable system



9-

No, because the system becomes unstable (from simulation)

P>4189.5 which makes the system unstable

$$e_{s.s.} \leq 0.01$$

$$e_{s.s.} = \frac{4}{1+K_p}$$

$$K_p = \lim_{s \to 0} G(s) =$$

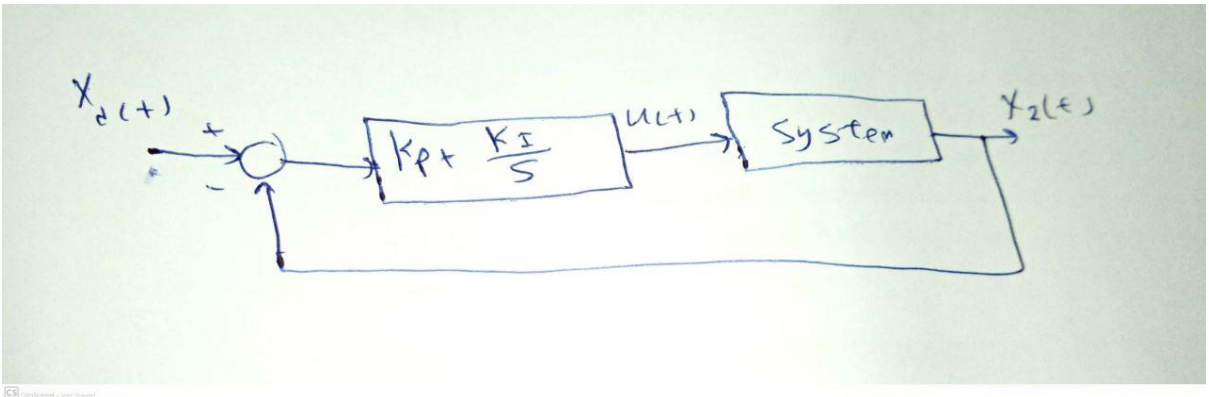
$$= \lim_{s \to 0} \frac{K_p(0.005)}{s^4 + 2s^3 + 2.1s^2 + 1.1s + 0.0525}$$

$$= \frac{K_p(0.005)}{0.0525} = \frac{2}{21} K_p$$

$$\frac{4}{1 + \frac{2}{21}P} \leq 0.01$$

$$\therefore P \geq 4189.5$$

10-



For Kp=100,Ki=10 ➔ Steady state error of X2 is 0.000001