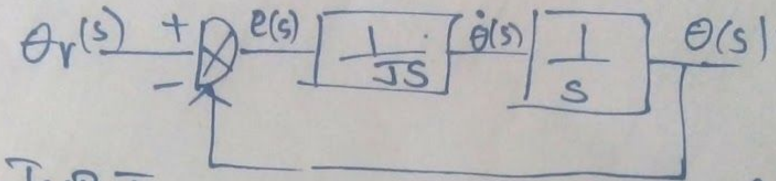
PROBLEM 1 ①

a) $\dot{\omega} = \frac{1}{J} u$ Space Craft System



$\theta_r(S) \rightarrow$ INPUT

$\theta(S) \rightarrow$ OUTPUT

$e(s) \rightarrow$ errour Signal

$\frac{1}{JS} \rightarrow$ System

Closed loop

$$CL(s) = \frac{G(s)}{1+G(s)H(s)}$$

$\omega_n = 3$ rad/sec

$\zeta = 0.7$

"J = 2000" momentum of inertia

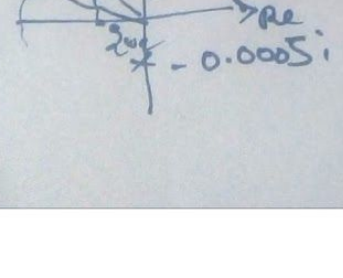
$$\Rightarrow \frac{\frac{1}{JS^2}}{1+\frac{1}{JS^2}(1)} \Rightarrow \frac{\frac{1}{JS^2}}{\frac{JS^2+1}{JS^2}}$$

$$C_L(s) \Rightarrow \frac{1}{JS^2+1} \Rightarrow \frac{1}{S^2+1/J} =$$

Stability

$S = \pm 0.0224i$

System is Marginally Stable



$$T_S = \frac{4}{\zeta \omega_n}$$

$T_S = 1.90476$ sec

Phase Margin (deg) = 128

Given System, want to Maintain System requirement

Zeros added to the system

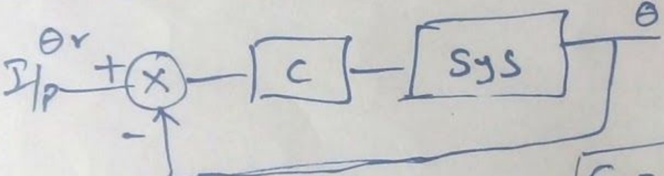
$$\frac{(s+2.1)}{(s+1/J)}$$ → This transfer function applied to root locus, & changed to our requirement $\xi = 0.7$ $\omega_n = 3.0$ forming

So, it gives Compensator value using "Control System designer" Tool box MATLAB

C → Compensator

$C = 18256 \times (1 + 0.48\, s)$

$\boxed{S = -2.17 + 2i}$



$\boxed{C = 8763S + 18256}$

$$T_s = \frac{1}{\xi \omega_n}$$

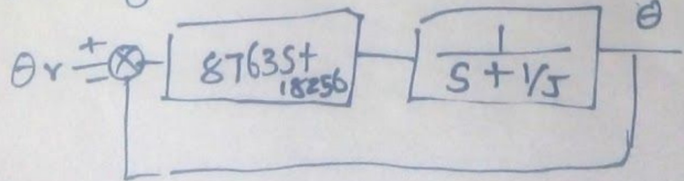
$\xi = 0.749$

$\omega_n = 3.0$

$T_s = 1.842146$ sec

But Simulation MATLAB Settling time $T_s = 1.63$ sec

New System



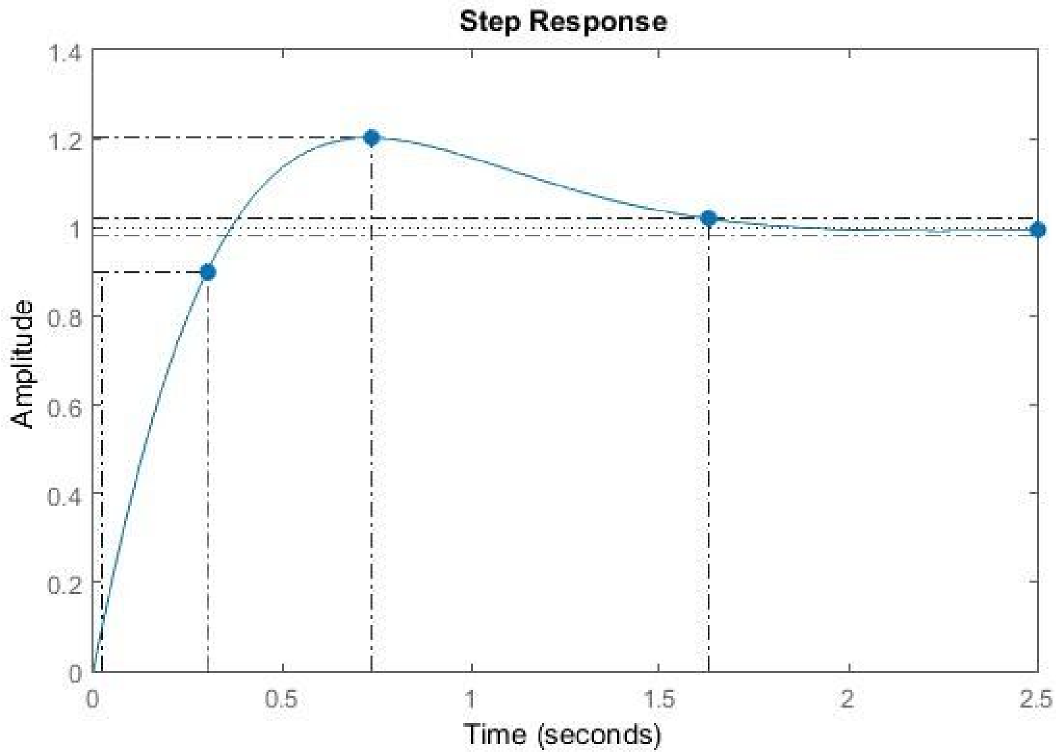


Fig 1:MATLAB Simulation Problem 1 .a

PROBLEM 1

b)

$$\frac{\theta}{U}(s) = \frac{\left(\left(\frac{s}{1.0}\right)^2 + 2\xi\frac{s}{1.0} + 1\right)}{J s^2\left(\left(\frac{s}{1.3}\right)^2 + 2\xi\left(\frac{s}{1.3}\right) + 1\right)}$$

$J = 2000$ kg
Moment of inertia

$$\frac{\theta}{U}(s) = \frac{s^2 + 2\xi s + 1}{J(0.591s^4 + 0.7692\xi s^3 + s^2)}$$

$\boxed{\xi = 0.002}$ damping ratio

$$\frac{\theta}{U}(s) = 0.0005 * \left[\frac{s^2 + 0.04s + 1}{0.591s^4 + 0.7692 * 0.002s^3 + s^2}\right]$$

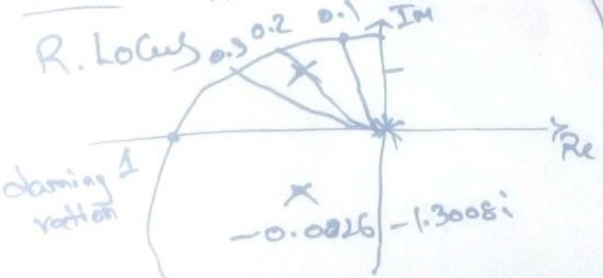
$$\frac{\theta}{U}(s) = 0.0005 * \left[\frac{s^2 + 0.04s + 1}{0.591s^4 + 0.030768s^3 + s^2}\right]$$

STABILITY

Poles:-
0.000 + 0.0000i
0.0000 + 0.0000i
−0.0026 + 1.3008i
−0.0026 − 1.3008i

LHP:- System is stable

R. Locus



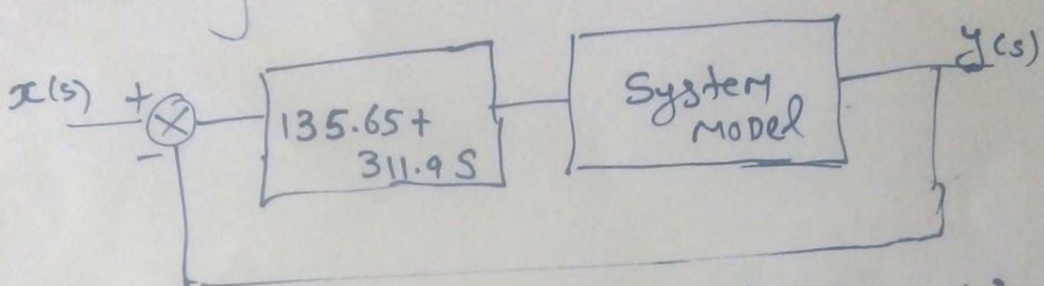
To maintain $\xi = 0.3 <$ damping ratio, original damping ratio
$\xi = 0.285$

Compensator value,

$$C = 135.65 * \frac{(1 + 2.3s)}{1}$$

Value compensator obtain from "root locus" plot from the "MATLAB"

Adding zeros at the numerator it Makes the System to handle at fixed damping ratio



Numerator zero value location is (S+0.439)

Controller = 135.65 + 311.9 S which act as K & KD Controller for the given System, whole information analyzed by using "Control System designer Tool" "MATLAB".

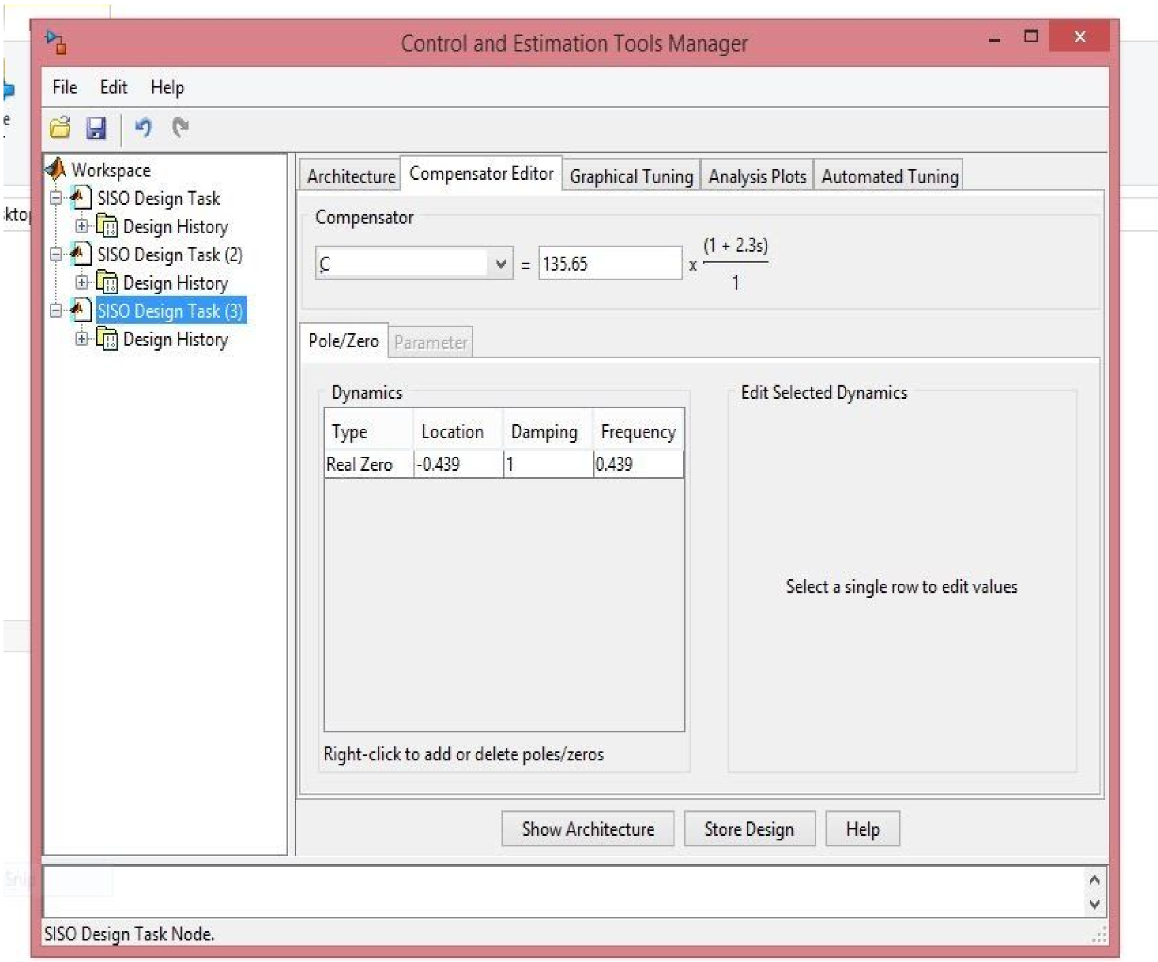


Fig 2 :MATLAB Simulation Problem 1 .b

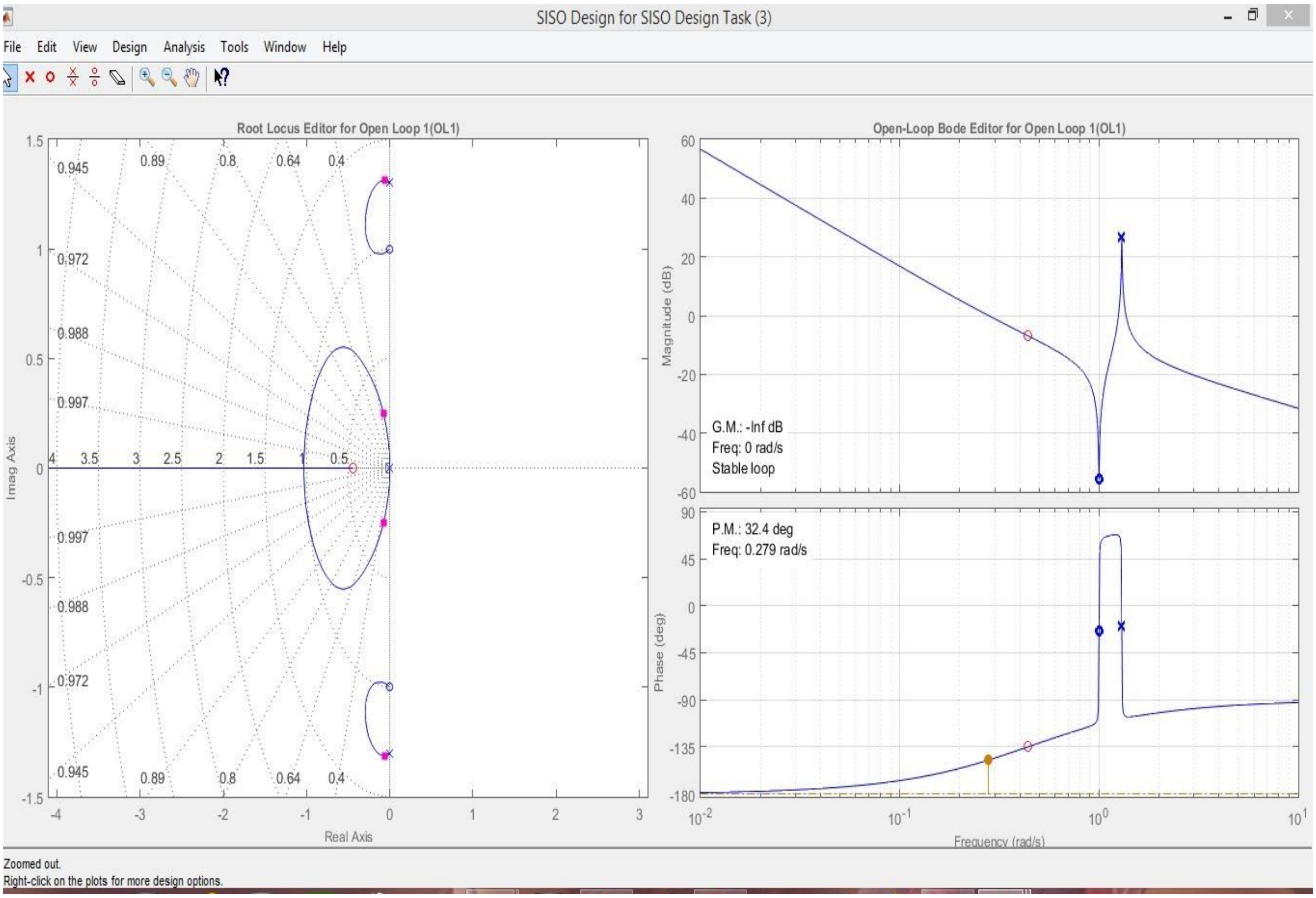


Fig 3 :MATLAB Simulation Problem 1 .b

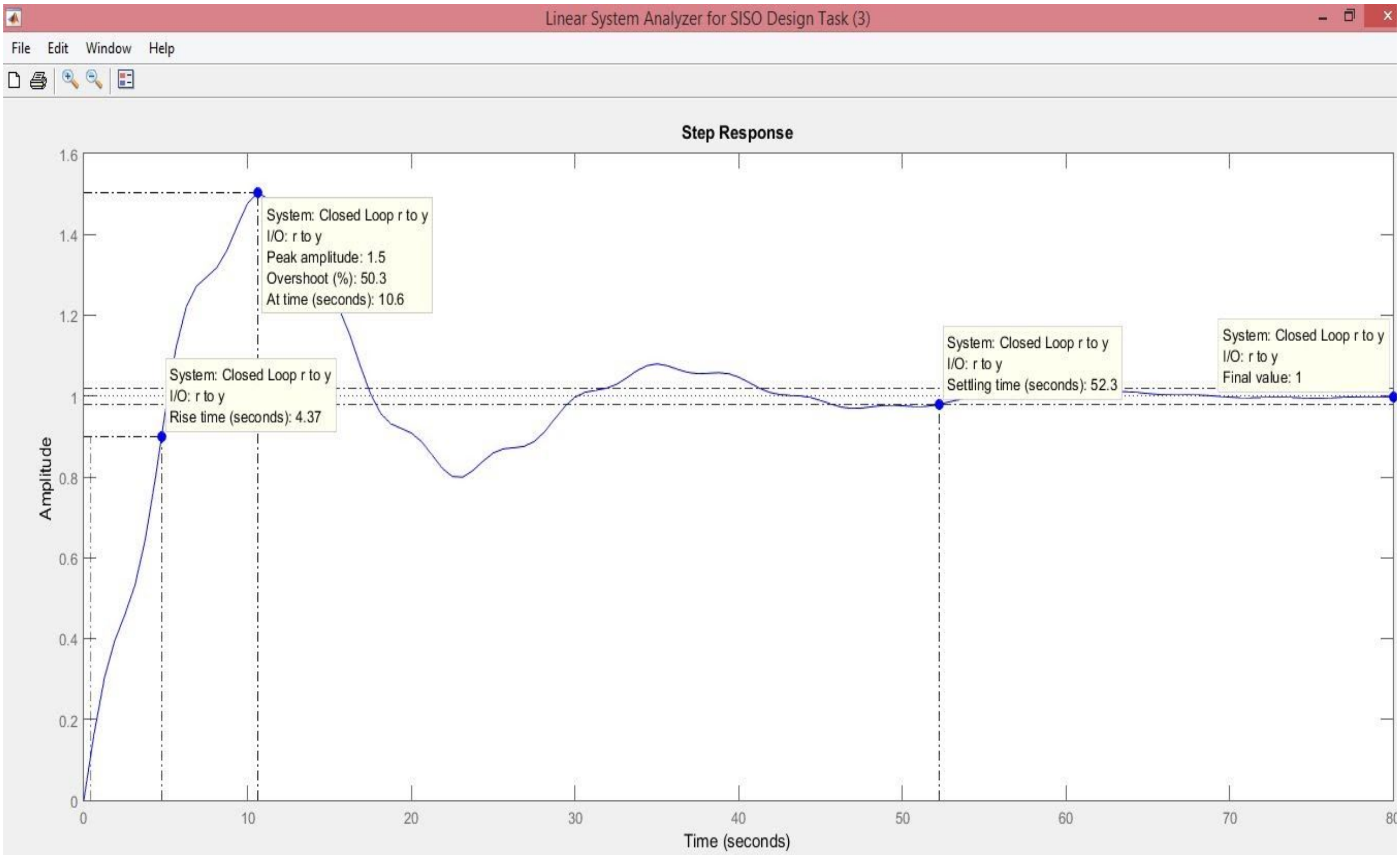


Fig 4:MATLAB Simulation Problem 1 .b

PROBLEM 2 :-

SYSTEM TRANSFER FUNCTION

$$G(s) = \frac{2.5}{S(s^2 + 10.5S + 5)}$$

Poles $= -10{,}000, -0.5, 0$

$\therefore$ which, shows system is stable

To find steady state error :-

[RAMP INPUT]

K_v = Constant

$$K_v = \lim_{S \to 0} S\, G(s)$$

$$K_v = \lim_{S \to 0} S \left[\frac{2.5}{S(s^2 + 10.5S + 5)}\right]$$

$$K_v = 0.5$$

error $e(\infty) = 1/K_v$

$$e(\infty) = 2$$

But want to manitain $< 10\%$.

$K > 20$

$K_v = 0.5 \Rightarrow \frac{K\,2.5}{5}$ It reaches $< 10\%$.

Routh Table (Closed loop with K & G(S))

s^3	1	5
s^2	10.5	2.5K
s^1	$\frac{52.5-2.5K}{10.5}$	0
s^0	2.5K	

$52.5 = 2.5K$

$K = 21 \qquad \omega = 2\pi f$

$10.5s^2 + 2.5K = 0$

$-10.5\,\omega^2 + 2.5(21) = 0$

$\omega = \sqrt{5}$

$\omega = 2.236 \qquad T_u = \frac{2\pi}{\sqrt{5}}$

$T_u = 2.8099$

Z-N METHOD a) $K = 16.8$ Not closed to "zero Steady State error"

b) PD - $P = 0.8 \times K$ $P = 16.8$

$D = K_p T_u/8$ $D = \frac{59.0079}{8} = 7.3759$

It closer to "zero steady error"

c) PID

$K_p = 0.8 * K = 16.8$

$T_i = T_u/2 = 1.4049$

$T_d = T_u/8 = 0.3512375$

$K_i = \frac{K_p}{T_i} \Rightarrow 11.958$

$K_D = K_p T_D \Rightarrow 5.9007$

PID Controller reaches the "Zero Steady State error"

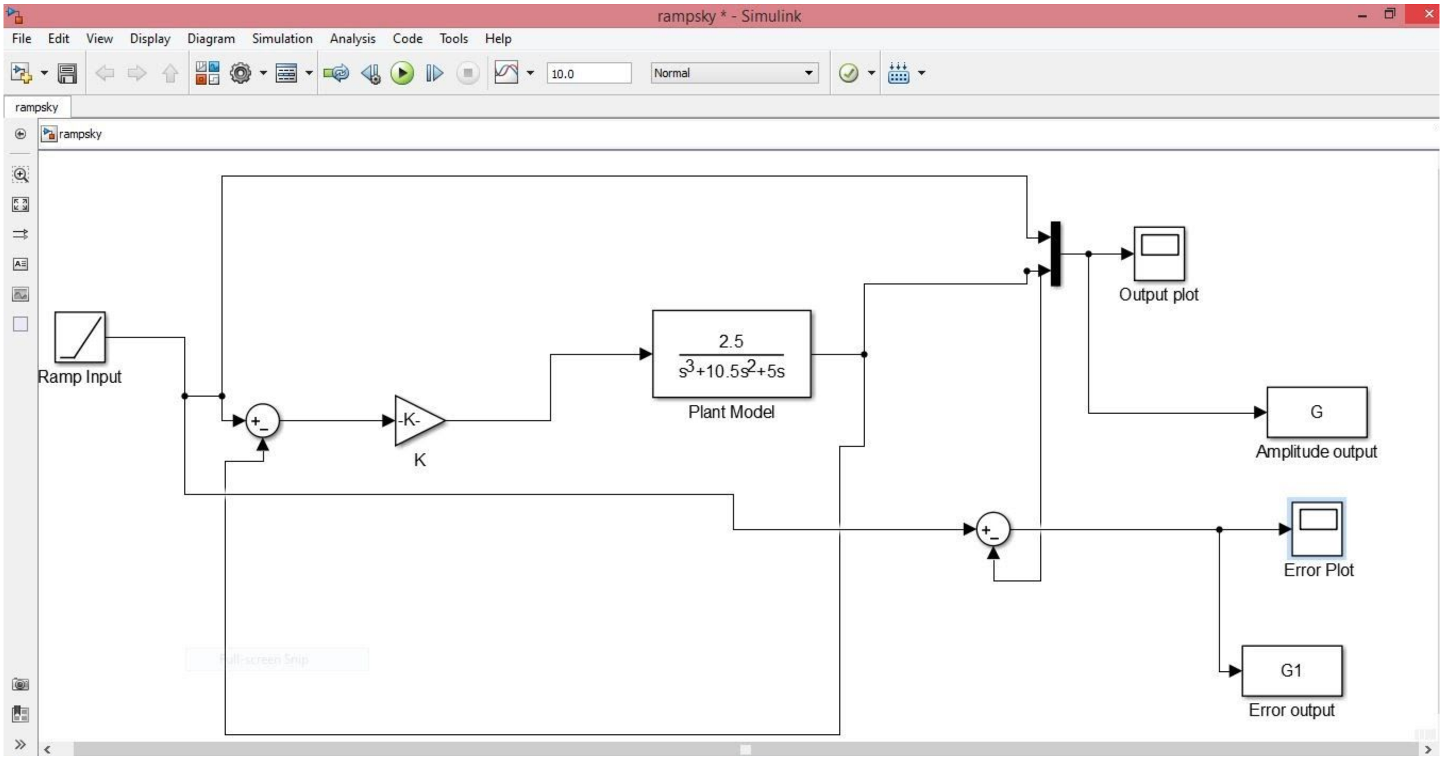


Fig 5 :MATLAB Simulation(P controller) Problem 2 a

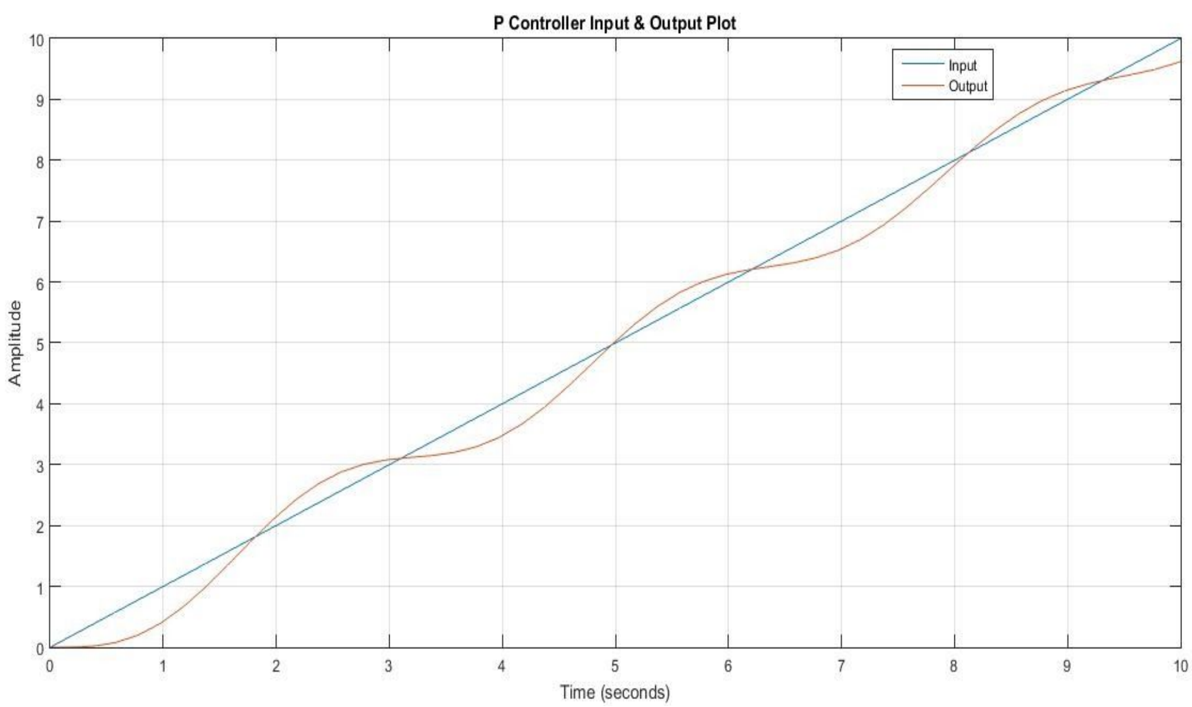


Fig 6 :MATLAB Simulation(Ramp Response of P controller) Problem 2 a

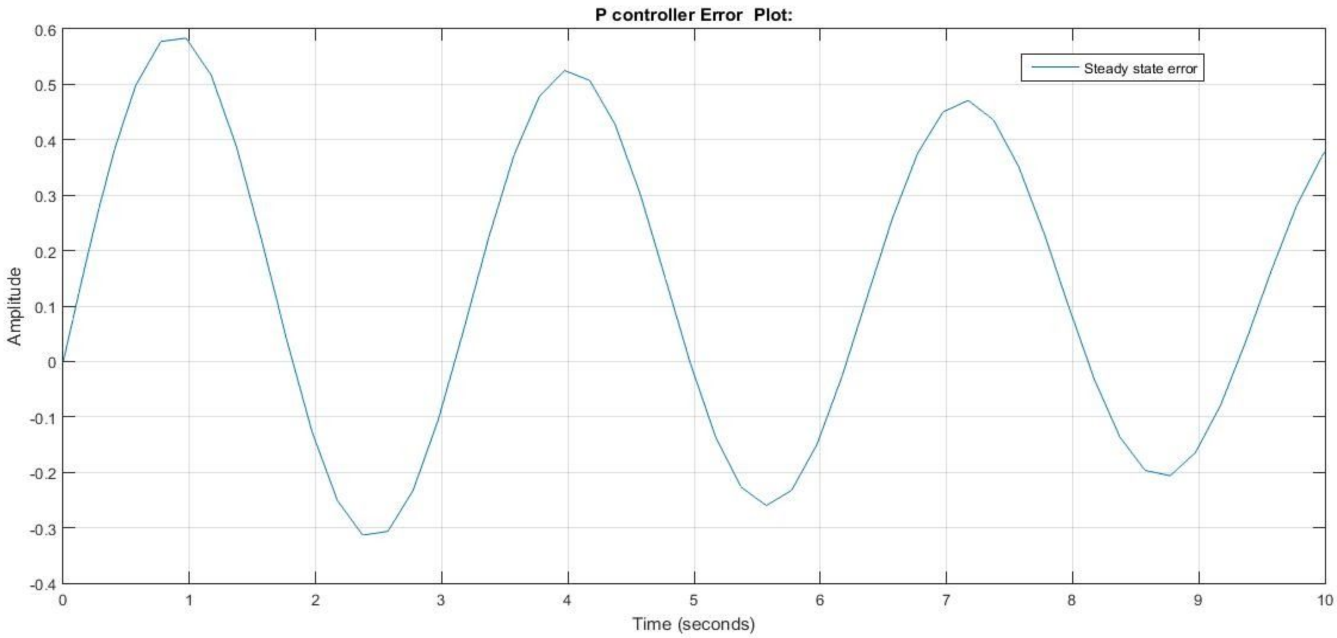


Fig 7 :MATLAB Simulation(Steady state error Ramp Response of P controller) Problem 2 a

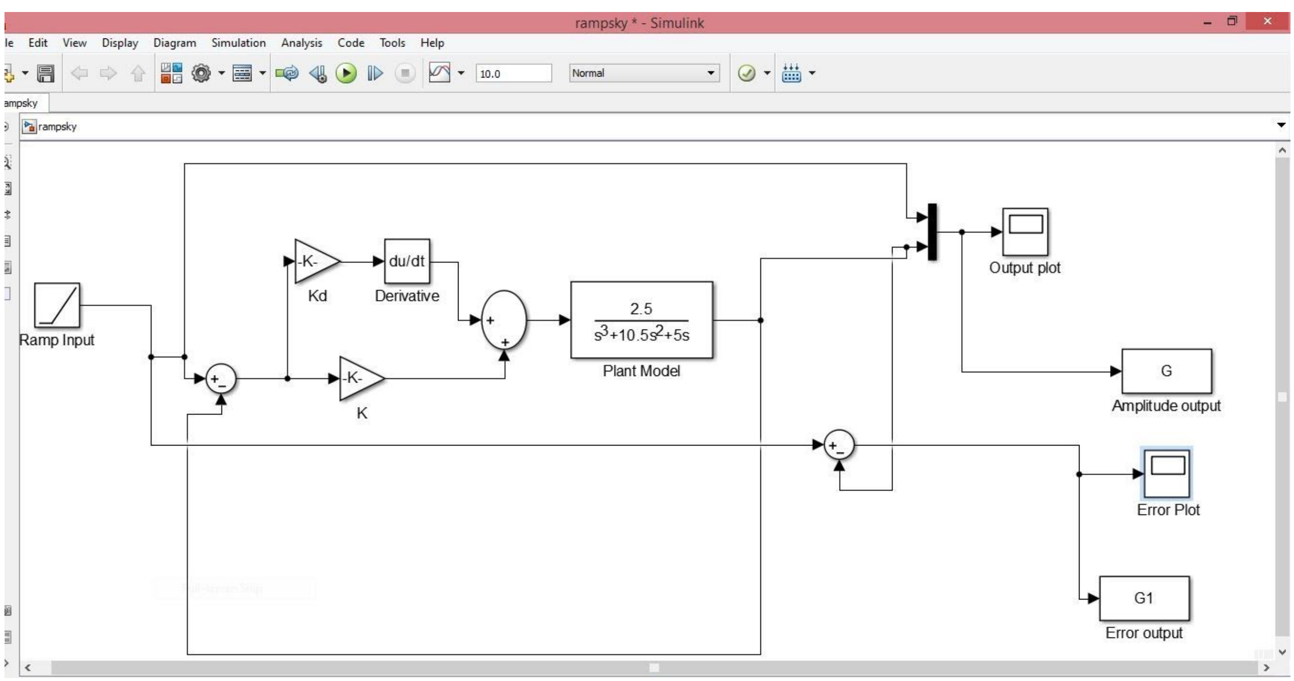


Fig 8 :MATLAB Simulation(PD controller) Problem 2 b

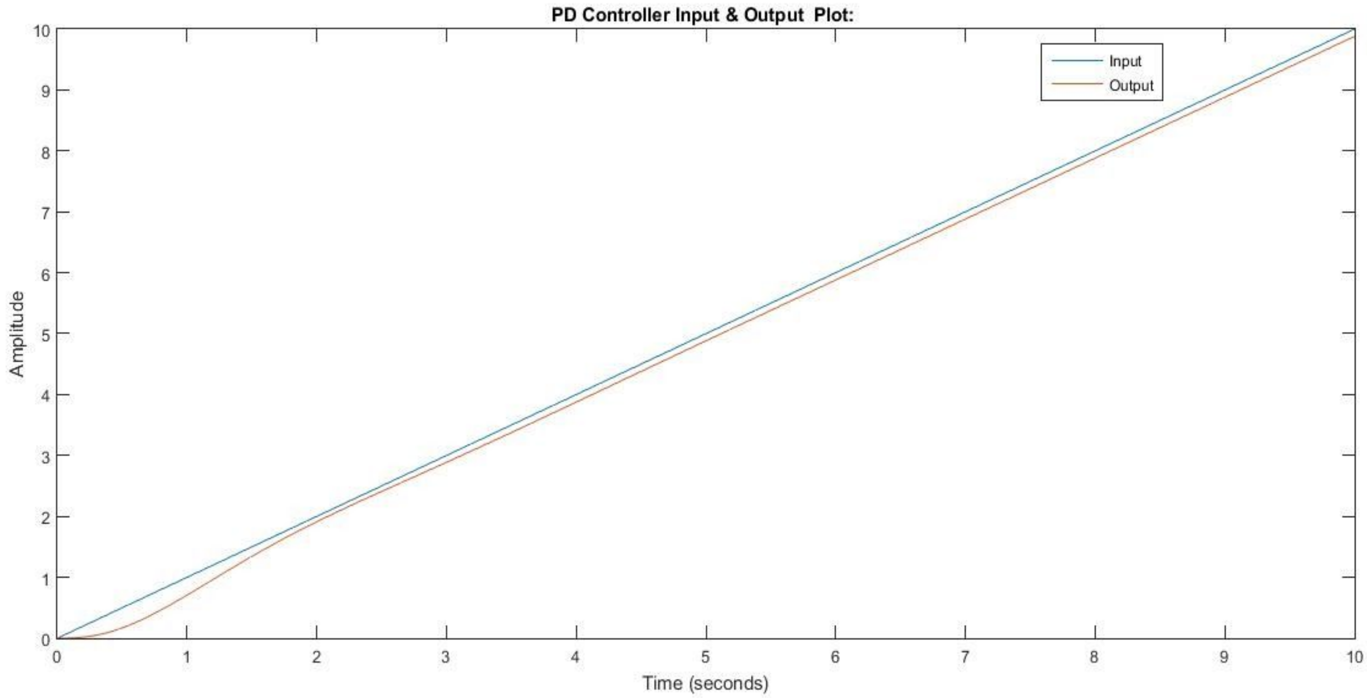


Fig 9 :MATLAB Simulation(Ramp Response of PD controller) Problem 2 b

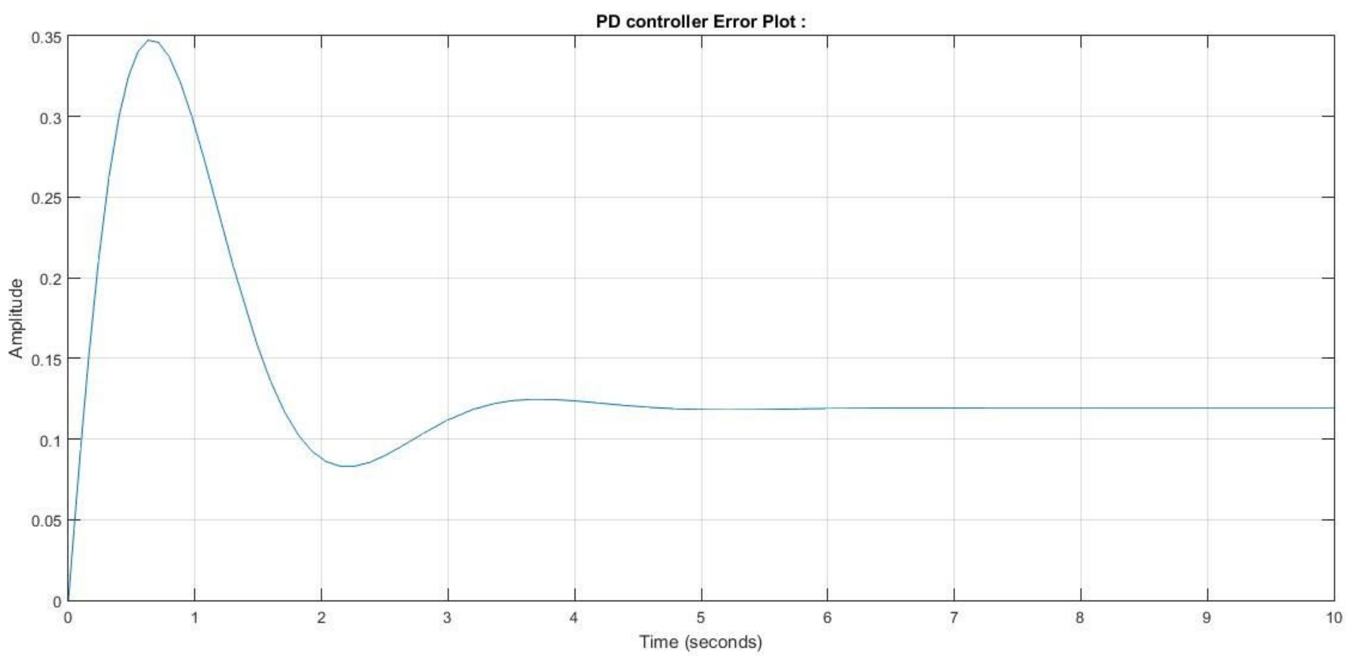


Fig 10 :MATLAB Simulation(Steady state error Ramp Response of PD controller) Problem 2 b

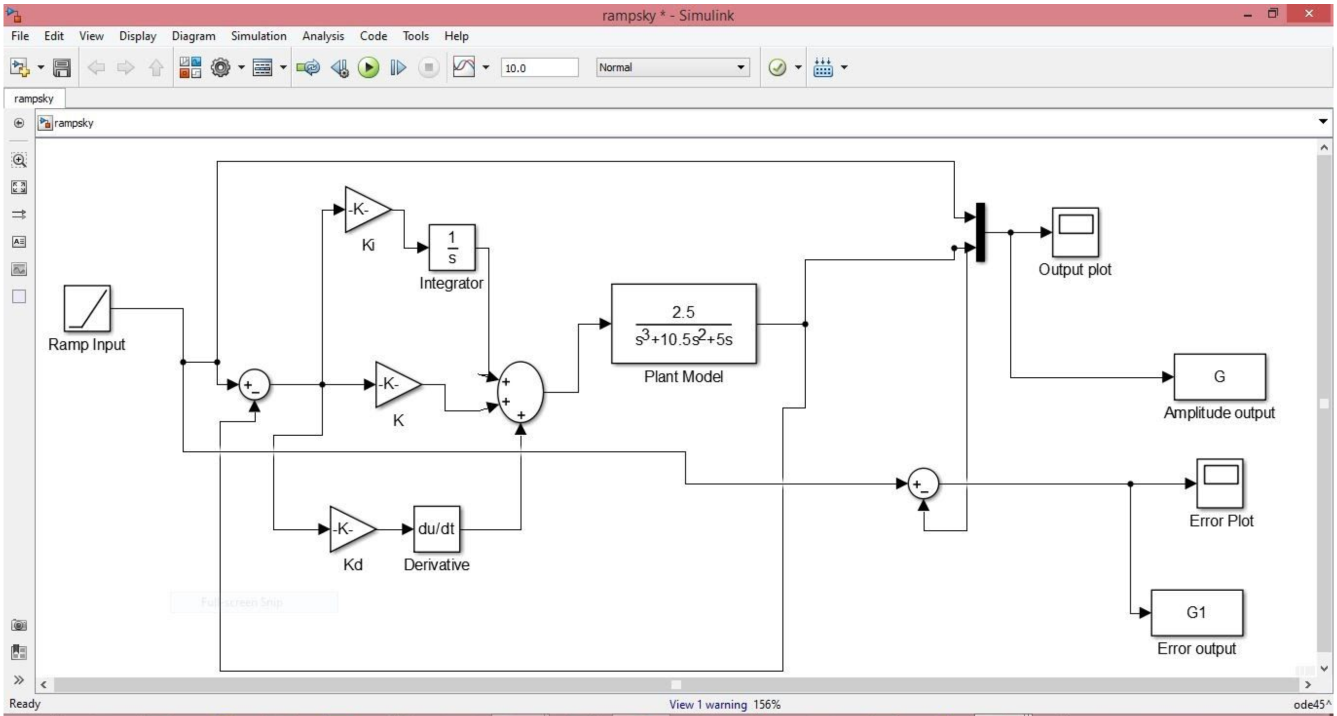


Fig 11 :MATLAB Simulation(PID controller) Problem 2 c

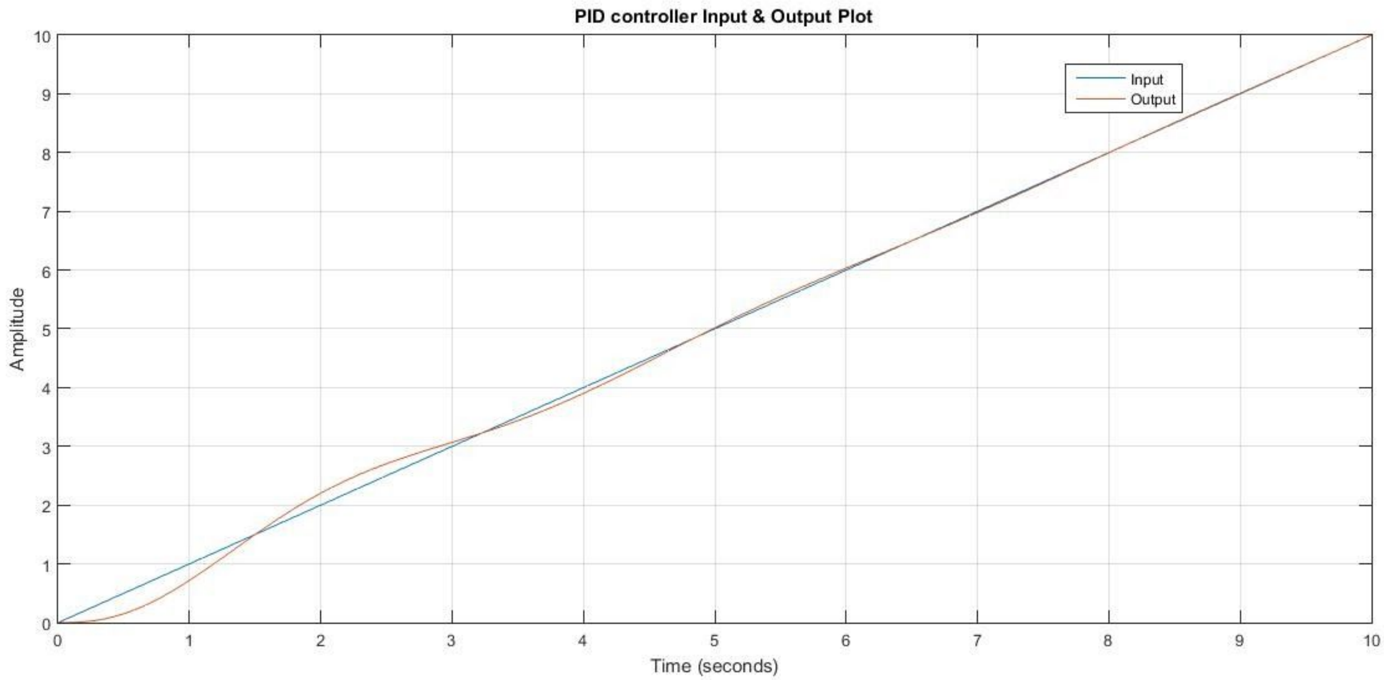


Fig 12 :MATLAB Simulation(Ramp Response of PID controller) Problem 2 c

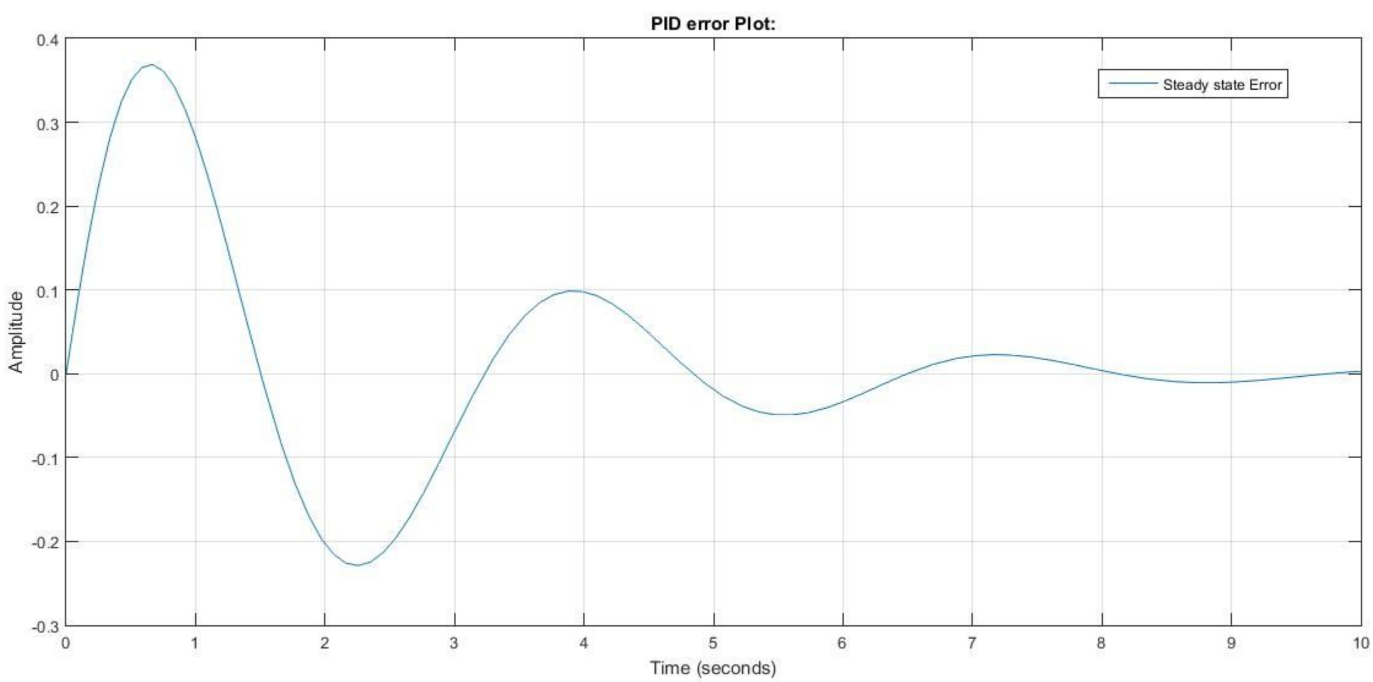
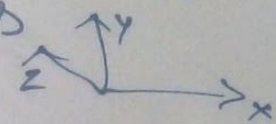
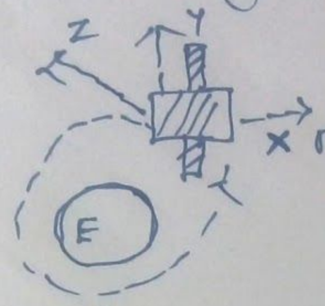


Fig 13 :MATLAB Simulation(Steady state error Ramp Response of PID controller) Problem 2 c

PROBLEM 3 Euler angle (ϕ, θ, ψ) (7)

orientation body axis





$n = \sqrt{GM/r^3}$

$J_x = 300\ kg\,m^2$

$J_y = 400\ kg\,m^2$

$J_z = 150\ kg\,m^2$

$n = 1.107 \times 10^{-3}$

Case "a"

State Space-Matrix

$$\begin{bmatrix} \dot{\omega}_x \\ \dot{\omega}_y \\ \dot{\omega}_z \end{bmatrix} = \begin{bmatrix} 0 & -\tau_x/300 & 0 \\ 0 & -\tau_y/400 & 0 \\ 0 & -\tau_z/150 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Euler angle

$$\begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -n & n \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

System Matrix

$$A = \begin{bmatrix} 0 & 3.33e^{-05} & 0 \\ 0 & 2.500e^{-05} & 0 \\ 0 & 6.667e^{-05} & 0 \end{bmatrix}$$

Euler angle

$$A = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -0.0011 & 0.0011 \\ 0 & 0 & 0 \end{bmatrix}$$

Case "b"

System matrix

$$\begin{bmatrix} \dot{\omega}_x \\ \dot{\omega}_y \\ \dot{\omega}_z \end{bmatrix} = \begin{bmatrix} 0 & \frac{-\tau_x - \tau_z(-n)}{300} & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Euler angle

$$\begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ -n & 0 & n \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

System Matrix

$$A = \begin{bmatrix} 0 & -3.333e^{-05} & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Euler angle

$$A = \begin{bmatrix} 0 & 0 & 0 \\ -0.0011 & 0 & -0.0011 \\ 0 & 0 & 0 \end{bmatrix}$$

Comments:- Case 'b' show compare to case "a" it changing its direction y-axis. It shows case "b" change direction for verification case "a" Euler and case "b" Euler subtracted and identified from the information from MATLAB.

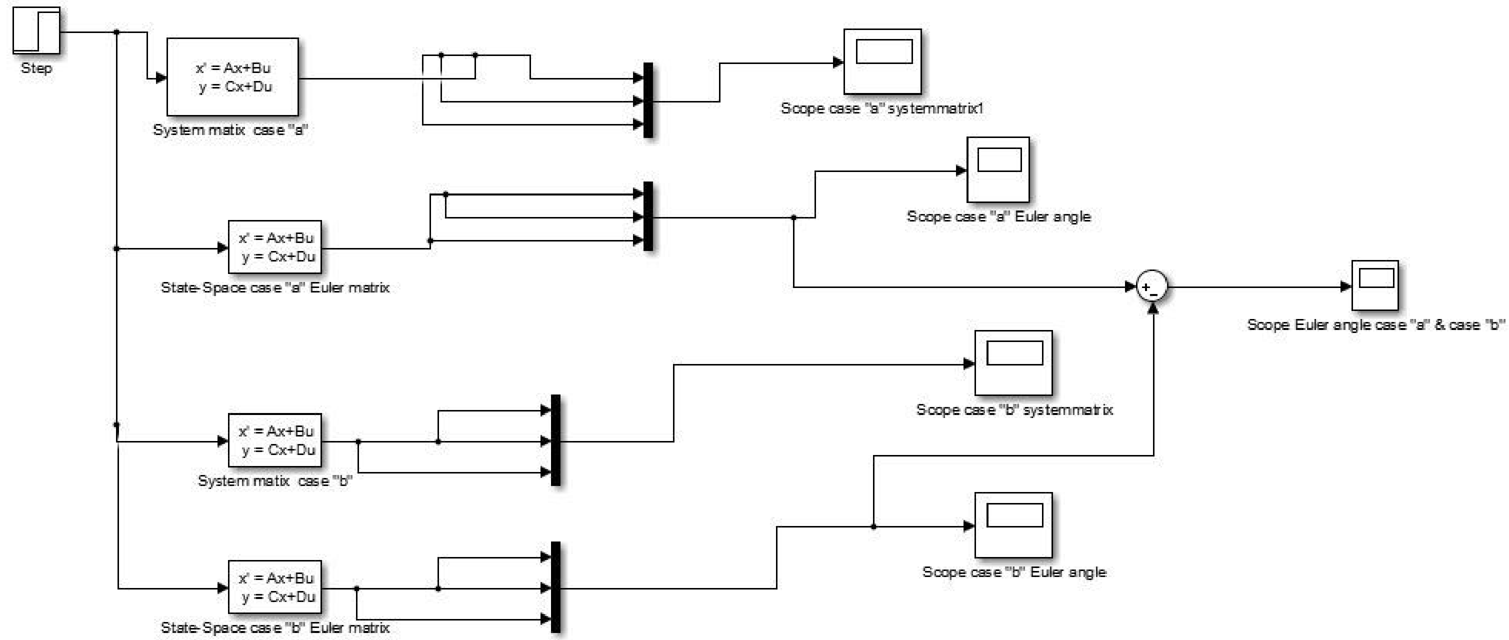


Fig 14 :MATLAB Simulation Case “a” & Case “b” Problem 3

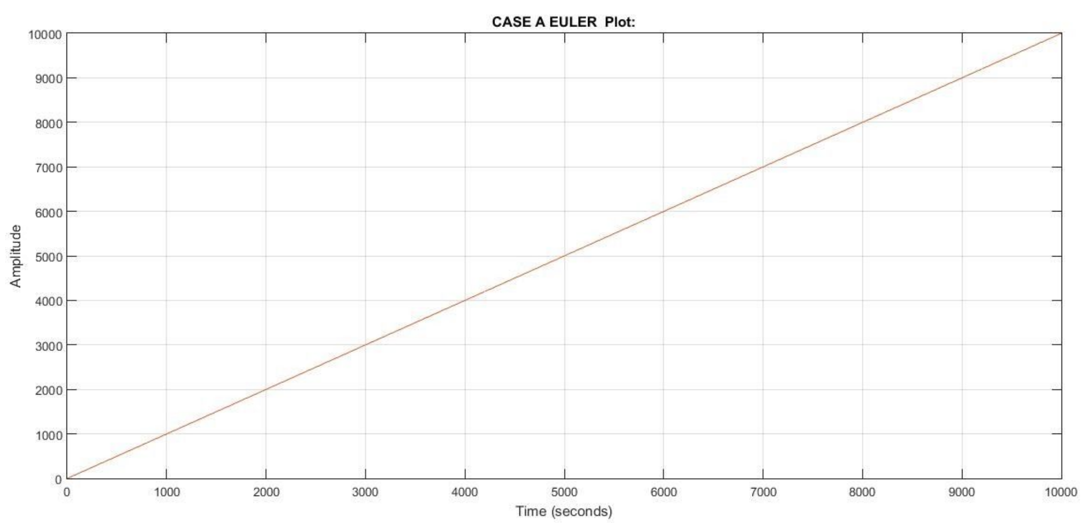


Fig 15 :MATLAB Simulation Euler Case “a” Problem 3

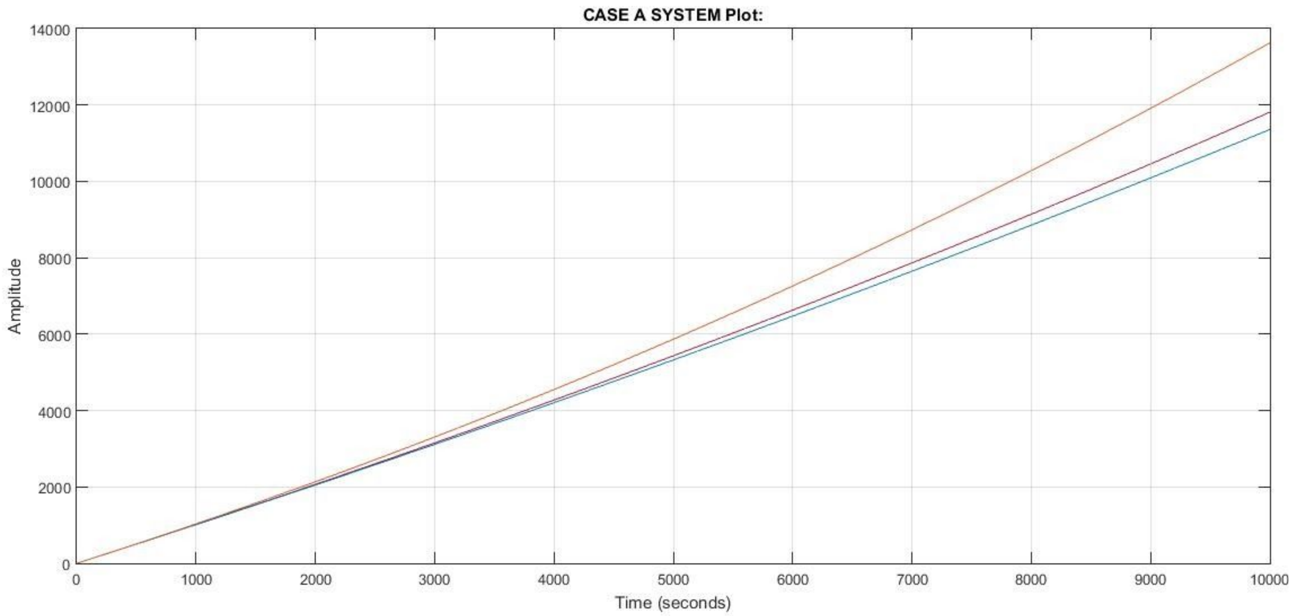


Fig 16 :MATLAB Simulation System Response Case “a”   Problem 3

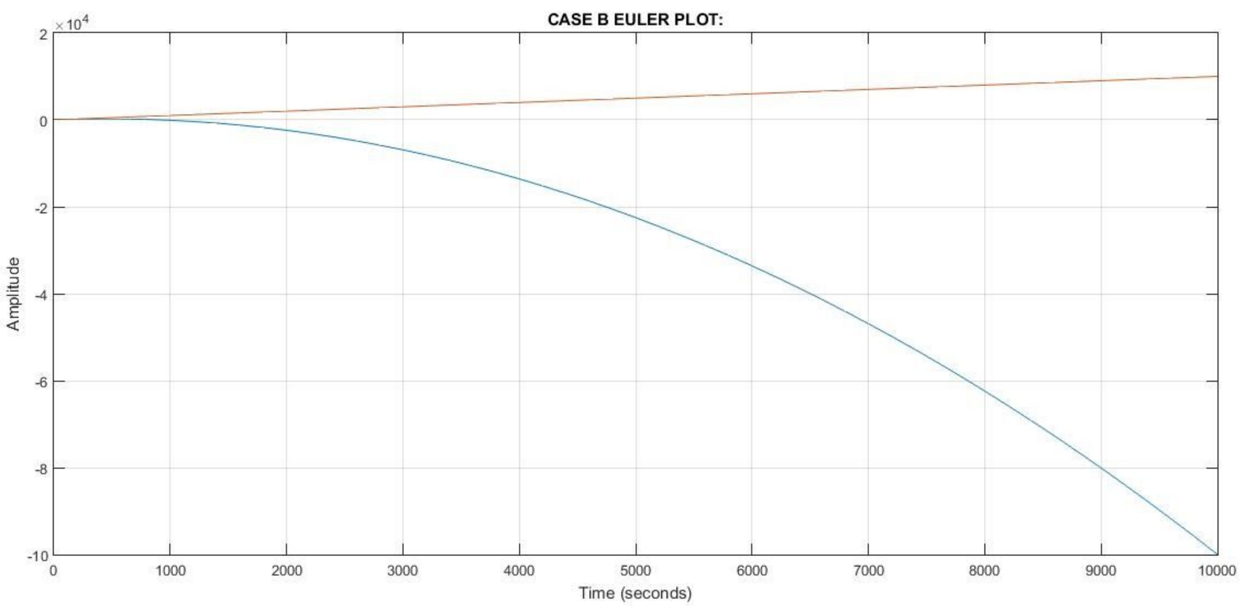


Fig 17 :MATLAB Simulation Euler Case “b” Problem 3

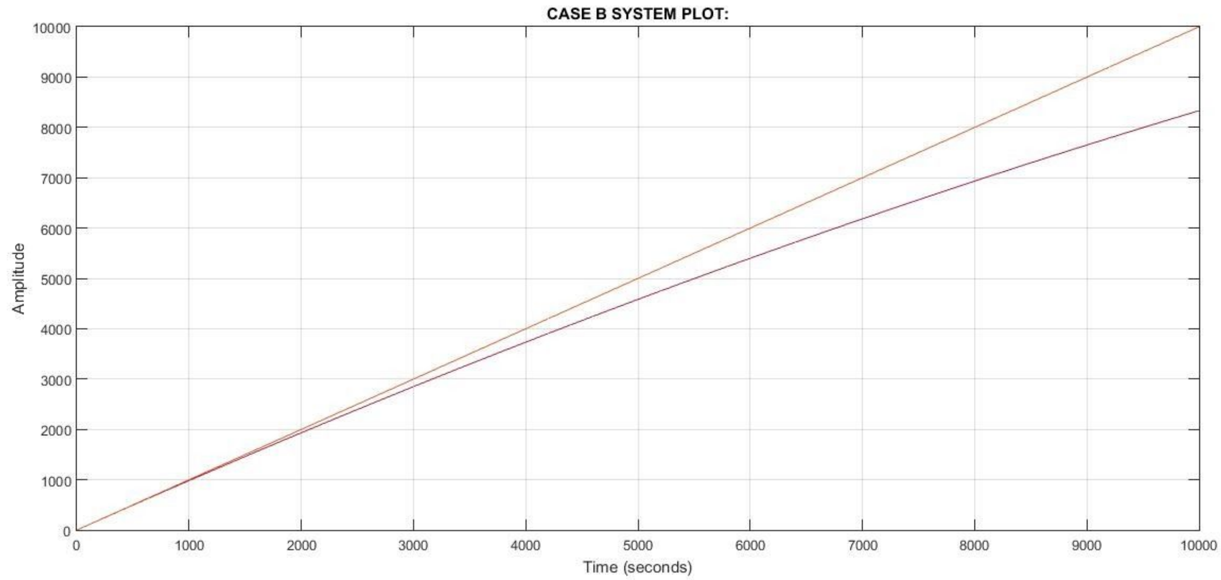


Fig 18 :MATLAB Simulation System Response of Case “b” Problem 3