FE :-

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix} = \begin{pmatrix} y \\ v_y \\ \psi \\ \dot{\psi} \\ \delta \end{pmatrix}$$

$$\dot{x}_1 = \dot{y} = v_x \sin\psi + v_y \cos\psi$$

$$\dot{x}_1 = v_x \sin(x_3) + x_2 \cos(x_3)$$

$$\dot{x}_2 = \dot{v}_y = \left(-\frac{c_1 + c_2}{m v_x}\right)(v_y) + \left(\frac{b c_2 - a c_1}{m v_x} - v_x\right)\dot{\psi} + \left(\frac{c_1}{m}\right)(\delta)$$

$$\dot{x}_2 = -\left(\frac{c_1 + c_2}{m v_x}\right)(x_2) + \left(\frac{b c_2 - a c_1}{m v_x} - v_x\right)(x_4) + \left(\frac{c_1}{m}\right)x_5$$

$$\dot{x}_3 = \dot{\psi} = x_4$$

$$\dot{x}_4 = \ddot{\psi} = -\left(\frac{a c_1 - b c_2}{J v_x}\right)(v_y) - \left(\frac{a^2 c_1 + b^2 c_2}{J v_x}\right)(\dot{\psi}) + \left(\frac{a c_1}{J}\right)\delta$$

$$= -\left(\frac{a c_1 - b c_2}{J v_x}\right)(x_2) - \left(\frac{a^2 c_1 + b^2 c_2}{J v_x}\right)(x_4) + \left(\frac{a c_1}{J}\right)x_5$$

$$\dot{\delta} = \dot{x}_5 = \left(\frac{-1}{\tau}\right)\delta + \frac{K_1}{\tau}u + \frac{K_2}{\tau}u^3$$

$$\dot{x}_5 = \dot{\delta} = \frac{-1}{\tau}x_5 + \frac{K_1}{\tau}u + \frac{K_2}{\tau}u^3$$

Linearise around $x_e = (0,0,0,0,0)$ and $u_e = 0$
straight fwd driving.

$$\Delta\dot{x} = A\,\Delta x + B\,\Delta u.$$

$$A = \begin{array}{c} \\ f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \end{array} \begin{array}{c} \begin{array}{ccccc} x_1 & x_2 & x_3 & x_4 & x_5 \end{array} \\ \left[\begin{array}{c|c|c|c|c} 0 & \cos(x_3) & v_x\cos x_3 - x_2\sin x_3 & 0 & 0 \\ 0 & a_{22} & 0 & a_{24} & (c_1/m) \\ 0 & 0 & 0 & 1 & 0 \\ 0 & a_{42} & 0 & a_{44} & \left(\frac{a c_1}{J}\right) \\ 0 & 0 & 0 & 0 & -1/\tau \end{array}\right] \end{array}$$

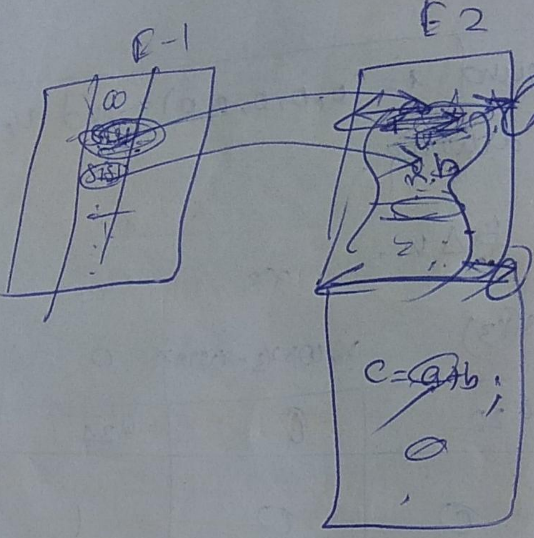
$$a_{22} = -\left(\frac{c_1+c_2}{m v_x}\right) \qquad a_{24} = \left(\frac{b c_2 - a c_1}{m v_x} - v_x\right)$$

~~a_{31}~~

$$a_{42} = -\left(\frac{a c_1 - b c_2}{J v_x}\right) \qquad a_{44} = -\left(\frac{a^2 c_1 + b^2 c_2}{J v_x}\right)$$

~~A~~ $B = \left[0;\ 0;\ 0;\ 0;\ \frac{K_1}{\tau} + \frac{3K_2 u^2}{\tau}\right]$

System is reachable and controllable.



De

De

10 – 3

Pole placement.

$\Delta u = -k\Delta x + K_r \Delta r$.

$P(s) = (s+P_1)^2 (s+P_2)^3$

$P_1 \Rightarrow$ satisfies settling time of 2s. (lane change maneuver).

Signal

unit

max

$P_2 \Rightarrow 3$ times (P_1)

O/P = y position

$C = [1\ 0\ 0\ 0\ 0]$

$$\left|\begin{array}{ccccc} s & -1 & -10 & 0 & 0 \\ 0 & s+10.588 & 0 & 9.411 & 0 \\ 0 & 0 & s & -1 & -47.05 \\ P & -0.5 & 0 & s+17.45 & 0 \\ 0 & 0 & 0 & 0 & 60.00 \\ & & & & s+10.00 \end{array}\right|$$

I S

~~Steering~~

$$\frac{\text{Lateral offset}}{\text{Steering angle}} = \frac{\frac{\cancel{(Kp)}\,Kp\,\omega_n^2}{(s^2+2\xi\omega_n s+\omega_n^2)}(Kp)}{1+\left(\frac{Kp\,\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}\right)}$$

$$= \frac{\frac{Kp}{s^2+2\xi\omega_n s+\omega_n^2}}{\frac{s^2+2\xi\omega_n s+(Kp+\omega_n^2)}{(s^2+2\xi\omega_n s+\omega_n^2)}}$$

$$= \frac{Kp}{s^2+2\xi\omega_n s+(Kp+\omega_n^2)}$$

$Kp = 0.002166$

$$\frac{1}{}$$

$$\frac{Kp}{s^2+2\xi\omega_n s+(Kp+\omega_n^2)}$$

$$= \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2} \qquad \frac{\boxed{0.002166}}{s^2+2C}$$

$\omega_n = 0.046541$

$\xi = 0.13066$

$\xi = 0.1306564$
$\omega_n = 0.046454$

$$\frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2} = \frac{0.0170735}{s^2 + 0.01216s + 0.01}$$

$$= \frac{K_p}{s^2 + 2\xi\omega_n s + (K_p + \omega_n^2)}$$

$K_p = 0.01707$

$2\xi\omega_n = 0.01216.$
$\omega_n^2 + K_p = 0.01707.$
$\omega_n^2 =$