Q) **Step 1:-**

Identifying i/p & o/p variables.

(i/p) (1) Temperature [0 - 45°C]	(2) Humidity [0-100%]
{VC, C, N, H}	{VD, D, N, W}
VC → Very Cold	VD → Very Dry
C → Cold.	D → Dry
N → Normal	N → Normal
H → Hot.	W → Wet.

(o/p) (1) AC Temperature [16-32°C]

{VC, C, N, H}

VC → Very cool

C → cool

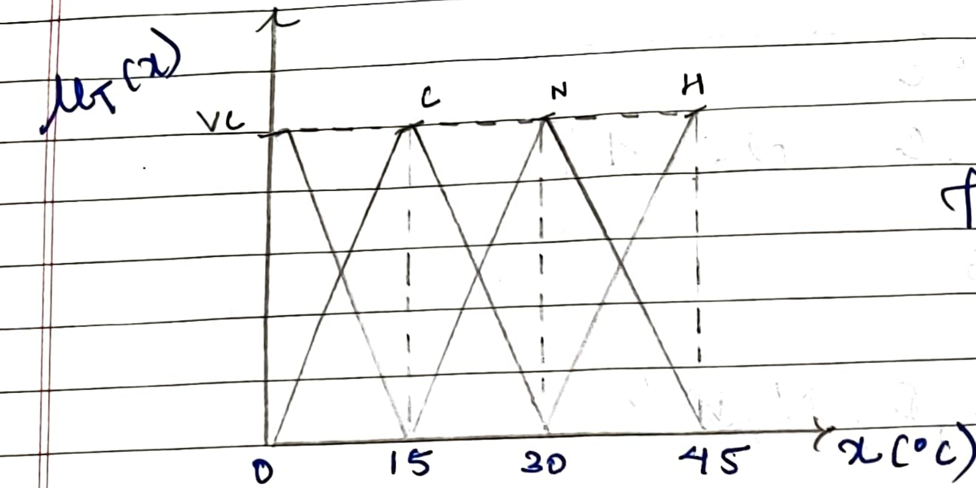
N → Normal

H → Hot.

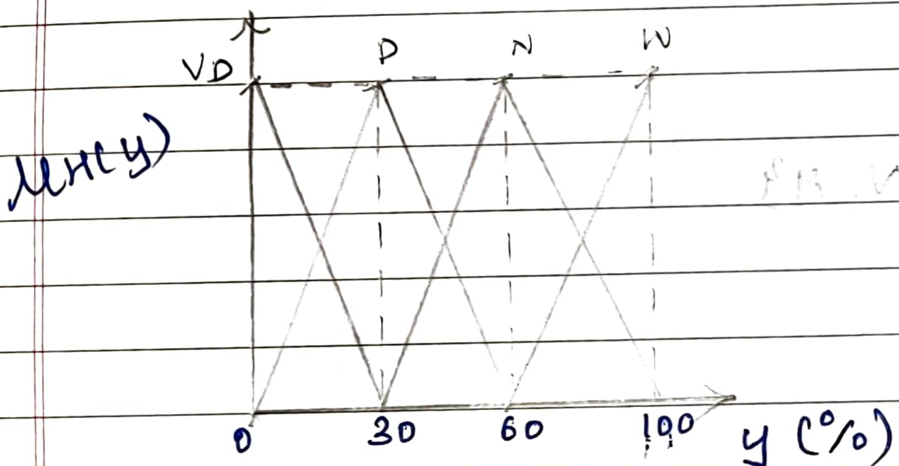
80 +45

~~[illegible]~~

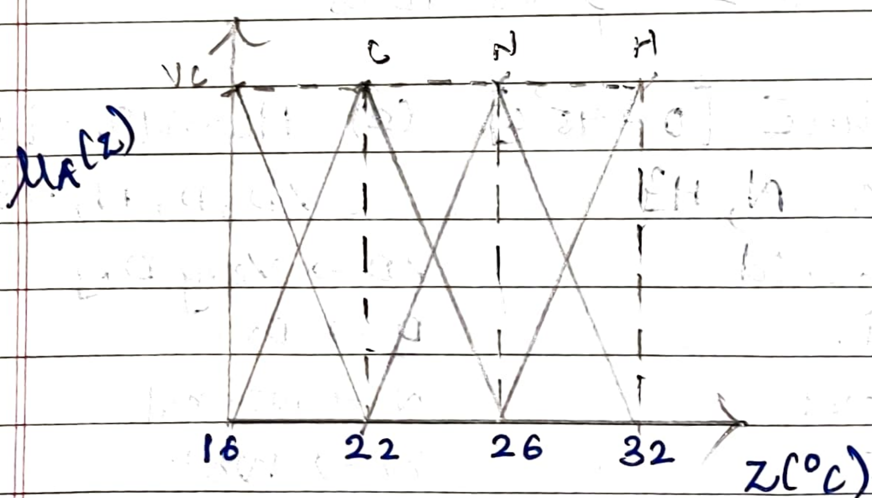
x)



Temperature (T)



Humidity (H)



AC-Temperature (A)

Step 2:- Assigning Membership fn's.

$$\mu_T(x) = \begin{cases} \mu_{VC}(x) = \dfrac{15-x}{15} \; ; \; 0 \le x \le 15 \\[2ex] \mu_C(x) = \begin{cases} x/15 \; ; \; 0 \le x \le 15 \\[1ex] \dfrac{30-x}{15} \; ; \; 15 \le x \le 30 \end{cases} \\[4ex] \mu_N(x) = \begin{cases} \dfrac{x-15}{15} \; ; \; 15 \le x \le 30 \\[1ex] \dfrac{45-x}{15} \; ; \; 30 \le x \le 45 \end{cases} \\[4ex] \mu_H(x) = (x-30)/15 \; ; \; 30 \le x \le 45 \end{cases}$$

$$\mu_H(y) = \begin{cases} \mu_{VD}(y) = (30-y)/30 \; ; \; 0 \le y \le 30 \\[2ex] \mu_D(y) = \begin{cases} y/30 \; ; \; 0 \le y \le 30 \\[1ex] 60-y/30 \; ; \; 30 \le y \le 60 \end{cases} \\[4ex] \mu_N(y) = \begin{cases} y-30/30 \; ; \; 30 \le y \le 60 \\[1ex] 100-y/40 \; ; \; 60 \le y \le 100 \end{cases} \\[4ex] \mu_H(y) = (y-60)/40 \; ; \; 60 \le y \le 100 \end{cases}$$

$$\mu_A(z) = \begin{cases} \mu_{VC}(z) = 22-x/6 \;; & 16 \le x \le 22 \\ \mu_C(z) = \begin{cases} x-16/6 \;; & 16 \le x \le 22 \\ 26-x/4 \;; & 22 \le x \le 26. \end{cases} \\ \mu_N(z) = \begin{cases} x-22/4 \;; & 22 \le x \le 26. \\ 32-x/6 \;; & 26 \le x \le 32 \end{cases} \\ \mu_H(z) = x-26/6 \;; & 26 \le x \le 32. \end{cases}$$

Step 3 :- 3.1 Build a Rule Base.

x \ y	VP	D	N	H
VC	H	H	~~H~~	N.
C	N	N	N	C
N	C	C	C	VC
H	VC	VC	VC	VC

~~Ste~~ 3.2 :- Rule evaluation

Temperature :- 36°C Humidity = 80%

$\mu_N(36) = (45-36)/15 = 9/15 = 3/5$
$\mu_H(36) = (36-30)/15 = 6/15 = 2/5.$

$\mu_N(80) = (100-80)/40 = 20/40 = 1/2$
$\mu_H(80) = (80-60)/40 = 20/40 = 1/2.$

3.3 Rule decision table

$x \backslash y$	$\mu_{VO}(y)$	$\mu_O(y)$	$\mu_N(y)$	$\mu_H(y)$
$\mu_{VC}(x)$	X	X	X	X
$\mu_C(x)$	X	X	X	X
$\mu_N(x)$	X	X	$\mu_C(z)$	$\mu_{VC}(z)$
$\mu_H(x)$	X	X	$\mu_{VC}(z)$	$\mu_{VC}(z)$

Step 4:- 4.1 min-max method

$\mu_N(36) \cap \mu_N(80) = 1/2$ $\qquad$ $\mu_H(36) \cap \mu_N(80) = 2/5$

$\mu_N(36) \cap \mu_H(80) = 1/2$ $\qquad$ $\mu_H(36) \cap \mu_H(80) = 2/5$

$$\max = (1/2, 1/2, 2/5, 2/5) = 1/2$$

4.2 :- Rule strength table.

$x \backslash y$	$\mu_{VO}(y)$	$\mu_O(y)$	$\mu_N(y)$	$\mu_H(y)$
$\mu_{VC}(x)$	X	X	X	X
$\mu_C(x)$	X	X	X	X
$\mu_N(x)$	X	X	1/2	1/2
$\mu_H(x)$	X	X	2/5	2/5

$\mu_C(z) = 1/2 \rightarrow \dfrac{z-16}{6_3} = \dfrac{1}{2_1}$ $\quad$ | $\quad$ $\dfrac{26-z}{4_2} = \dfrac{1}{2_1}$

$z = 16+3 = 19$ $\qquad$ or $z = 24$

$\therefore z = 21.5\,^\circ C$

Q2 i/p = total

(1) Mileage
[10,000 - 2,00,000]

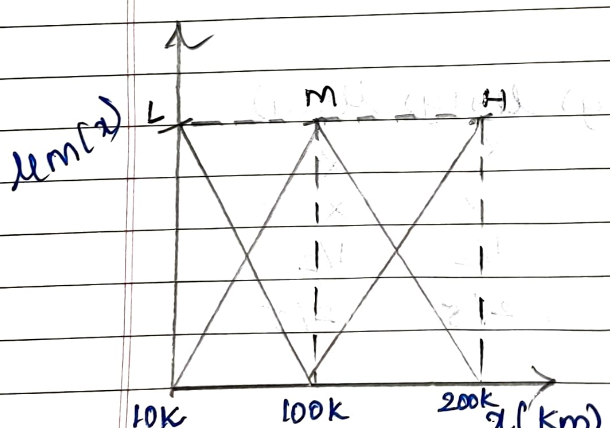
{L, M, H}
L → Low
M → Medium
H → High

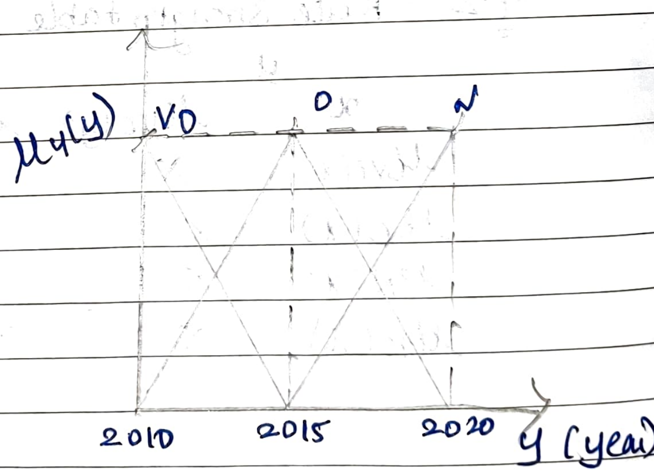
(2) Year of manufacture.
[2010 - 2020]
{VO, O, N}.

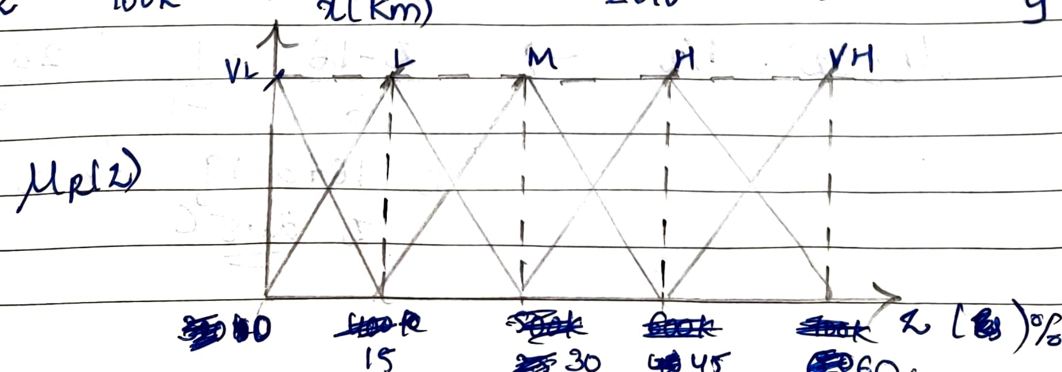
VO → Very Old
O → Old
N → ~~Normal~~ New.

O/p = Resale value {Assuming for Ciaz}
~~[3,00,000 - 7,00,000]~~ [0 - 60%]

{VL, L, M, H, VH}
VL → very ~~low~~ less.
L → ~~low~~ less
M → Medium
H → High
VH → very High







Step 2:- Assigning membership fn's.

$$\mu_L(x) = 100{,}000 - x/90{,}000 \; ; \; 10{,}000 \le x \le 100{,}000$$

$$\mu_m(x) = \begin{cases} \mu_m(x) = x - 10{,}000/90{,}000 & ; \; 10{,}000 \le x \le 100{,}000 \\ \mu_m(x) = 2{,}00{,}000 - x/1{,}00000 & ; \; 100{,}000 \le x \le 2{,}00000 \end{cases}$$

$$\mu_H(x) = x - 100{,}000/100000 \; ; \; 100000 \le x \le 200000$$

$$\mu_y(y) = \begin{cases} \mu_{VO}(y) = 2015 - y/5 & ; \; 2010 \le y \le 2015. \\ \mu_O(y) = \begin{cases} y - 2010/5 & ; \; 2010 \le y \le 2015 \\ 2020 - y/5 & ; \; 2015 \le y \le 2020. \end{cases} \\ \mu_N(y) = y - 2015/5 & ; \; 2015 \le y \le 2020. \end{cases}$$

$$\mu_R(z) = \begin{cases} \mu_{VL}(z) = 15 - z/15 & ; \; 0 \le z \le 15. \\ \mu_L(z) = \begin{cases} z/15 & ; \; 0 \le z \le 15 \\ 30 - z/15 & ; \; 15 \le z \le 30 \end{cases} \\ \mu_m(z) = \begin{cases} z - 15/15 & ; \; 15 \le z \le 30 \\ 45 - z/15 & ; \; 30 \le z \le 45. \end{cases} \\ \mu_H(z) = \begin{cases} z - 30/15 & ; \; 30 \le z \le 45 \\ 60 - z/15 & ; \; 45 \le z \le 60. \end{cases} \\ \mu_{VH}(z) = z - 45/15 & ; \; 45 \le z \le 60. \end{cases}$$

Step3 :-

3.1 Building a Rule Base.

x \ y	VO	O	N
L	L	H	VH.
M	L	M	H.
H	VL	L	M

Step1 :- Identifying i/p & o/p variables.

Q3 i/p

(1) Food Quality
[0-10] {VP, P, G, E}

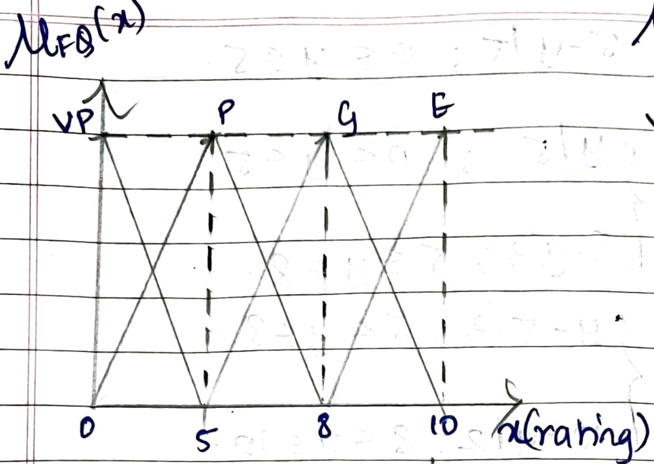
VP → Very Poor
P → Poor
G → Good
E → Excellent

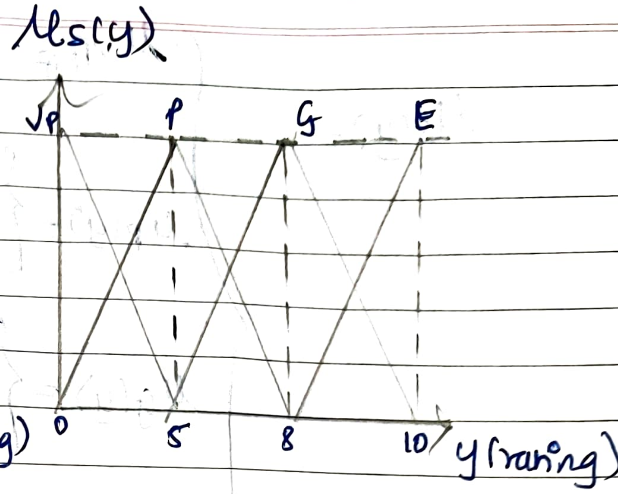
(2) Service
[0-10]
{VP, P, G, E}

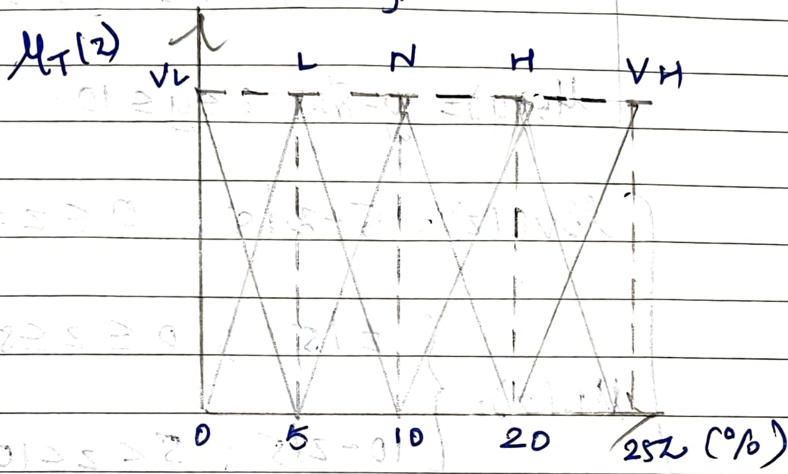
VP → Very Poor
P → Poor
G → Good
E → Excellent

o/p (1) Tip. [0 - 25%]
{VL, L, N, H, VH}

VL → Very less
L → less.
N → Normal
H → High
VH → very high







Step2:- Assigning membership functions.

$$\mu_{FQ}(x) = \begin{cases} \mu_{VP}(x) = 5-x/5; & 0 \le x \le 5 \\ \mu_P(x) = \begin{cases} x/5; & 0 \le x \le 5 \\ 8-x/3; & 5 \le x \le 8 \end{cases} \\ \mu_G(x) \begin{cases} x-5/3; & 5 \le x \le 8 \\ 10-x/2; & 8 \le x \le 10 \end{cases} \\ \mu_E(x) = x-8/2; & 8 \le x \le 10. \end{cases}$$

$$\mu_S(y) = \begin{cases} \mu_{VP}(y) = 5-y/5 \;;\; 0 \le y \le 5. \\[2ex] \mu_P(y) = \begin{cases} y/5 \;;\; 0 \le y \le 5. \\ 8-y/3 \;;\; 5 \le y \le 8. \end{cases} \\[2ex] \mu_G(y) = \begin{cases} y-5/3 \;;\; 5 \le y \le 8 \\ 10-y/2 \;;\; 8 \le y \le 10. \end{cases} \\[2ex] \mu_E(y) = y-8/2 \;;\; 8 \le y \le 10. \end{cases}$$

$$\mu_T(z) = \begin{cases} \mu_{VL}(z) = 5-z/5 \;;\; 0 \le z \le 5. \\[2ex] \mu_L(z) = \begin{cases} z/5 \;;\; 0 \le z \le 5. \\ 10-z/5 \;;\; 5 \le z \le 10. \end{cases} \\[2ex] \mu_N(z) = \begin{cases} z-5/5 \;;\; 5 \le z \le 10. \\ 20-z/10 \;;\; 10 \le z \le 20. \end{cases} \\[2ex] \mu_H(z) = \begin{cases} z-10/10 \;;\; 10 \le z \le 20 \\ 25-z/5 \;;\; 20 \le z \le 25 \end{cases} \\[2ex] \mu_{VH}(z) = z-20/5 \;;\; 20 \le z \le 25. \end{cases}$$

Slip3:-

3.1 Building a Rule Base.

x \ y	VP	P	G	E
VP	VL	VL	L	L
P	VL	L	L	N
G	L	N	H	H
E	L	N	VH	VH

Q4 Part 1

Given $x_1 = \begin{bmatrix} 1 \\ -2 \\ 3 \\ -1 \end{bmatrix}$ $x_2 = \begin{bmatrix} 0 \\ -1 \\ 2 \\ -1 \end{bmatrix}$ $x_3 = \begin{bmatrix} -2 \\ 0 \\ -3 \\ -1 \end{bmatrix}$ $w_4 = \begin{bmatrix} 3 \\ 2 \\ 6 \\ 1 \end{bmatrix}$

$c_1 = 1$ $d_1 = -1$ $d_2 = 1$ $d_3 - 1$

We have $d_3 = -1$ } since $d_i \neq O_i$

$w_4 = w_3 + \Delta w$ $O_3 = +1$

$$\begin{bmatrix} 3 \\ 2 \\ 6 \\ 1 \end{bmatrix} = w_3 + 1(-1-1) \cdot \begin{bmatrix} -2 \\ 0 \\ -3 \\ -1 \end{bmatrix}$$

$$\begin{bmatrix} 3 \\ 2 \\ 6 \\ 1 \end{bmatrix} = w_3 + \begin{bmatrix} 4 \\ 0 \\ 6 \\ 2 \end{bmatrix} \rightarrow w_3 = \begin{bmatrix} 3 \\ 2 \\ 6 \\ 1 \end{bmatrix} - \begin{bmatrix} 4 \\ 0 \\ 6 \\ 2 \end{bmatrix} = \begin{bmatrix} -1 \\ 2 \\ 0 \\ -1 \end{bmatrix}$$

We have

$w_3 = w_2 + \Delta w'$

Here $d_2 \neq O_2$ $\therefore d_2 = 1$

$w_3 = w_2 + c \cdot (d_2 - O_2) \cdot x_2$ $O_2 = -1$

$$\begin{bmatrix} -1 \\ 2 \\ 0 \\ -1 \end{bmatrix} = w_2 + (1 - -1) \cdot \begin{bmatrix} 0 \\ -1 \\ 2 \\ -1 \end{bmatrix}$$

$$\begin{bmatrix} -1 \\ 2 \\ 0 \\ -1 \end{bmatrix} = w_2 + \begin{bmatrix} 0 \\ -2 \\ 4 \\ -2 \end{bmatrix} \rightarrow w_2 = \begin{bmatrix} -1 \\ 2 \\ 0 \\ -1 \end{bmatrix} - \begin{bmatrix} 0 \\ -2 \\ 4 \\ -2 \end{bmatrix} = \begin{bmatrix} -1 \\ 4 \\ -4 \\ 1 \end{bmatrix}$$

We have,

$$w_2 = w_1 + \Delta w'$$

$$\begin{bmatrix} -1 \\ 4 \\ -4 \\ 1 \end{bmatrix} = w_1 + c \cdot (d_1 - o_1) \cdot X_1$$

Here, $d_1 = -1$ $o_1 = 1$ S_{En}^{o}

$$\begin{bmatrix} -1 \\ 4 \\ -4 \\ 1 \end{bmatrix} = w_1 + -2 \cdot \begin{bmatrix} 1 \\ -2 \\ 3 \\ -1 \end{bmatrix}$$

$$w_1 = \begin{bmatrix} -1 \\ 4 \\ -4 \\ 1 \end{bmatrix} - \begin{bmatrix} -2 \\ 4 \\ -6 \\ 2 \end{bmatrix} = \underline{\underline{\begin{bmatrix} 1 \\ 0 \\ 2 \\ -1 \end{bmatrix}}}$$

~~part 2~~

$X_1 = \begin{bmatrix} 1 \\ -2 \\ 3 \\ -1 \end{bmatrix} \quad X_2 = \begin{bmatrix} 0 \\ -1 \\ 2 \\ -1 \end{bmatrix} \quad X_3 = \begin{bmatrix} -2 \\ 0 \\ -3 \\ -1 \end{bmatrix}$

$d_1 = -1 \quad d_2 = 1 \quad d_3 = -1.$

$C = 1.$

$w_4 = [3, 2, 6, 1]$

~~w5~~ Step1:-

$net_4 = w_4 \cdot X_1$

$= [3 \; 2 \; 6 \; 1] \begin{bmatrix} 1 \\ -2 \\ 3 \\ -1 \end{bmatrix}$

$= 3 - 4 + 18 - 1$

$net_4 = 16.$

$O_1 = 1$

$d_1 = -1 \quad \therefore O_1 \neq d_1$

Hence, change weights.

$\Delta w' = C \cdot (d_1 - O_1) \cdot X_1$

$= 1 \cdot (-1 - 1) \cdot \begin{bmatrix} 1 \\ -2 \\ 3 \\ -1 \end{bmatrix} = \begin{bmatrix} -2 \\ 4 \\ -6 \\ 2 \end{bmatrix}$

$w_5 = w_4 + \Delta w'$

$= \begin{bmatrix} 3 \\ 2 \\ 6 \\ 1 \end{bmatrix} + \begin{bmatrix} -2 \\ 4 \\ -6 \\ 2 \end{bmatrix} = \begin{bmatrix} 1 \\ 6 \\ 0 \\ 3 \end{bmatrix}$

Step2:-

$net2 = W5 \times X2.$

$$= [1\ 6\ 0\ 3] \cdot \begin{bmatrix} 0 \\ -1 \\ 2 \\ -1 \end{bmatrix}$$

$= 0 - 6\ 0 - 3$

$net = -9$

$O2 = -1$

$d2 = 1 \quad \therefore O2 \neq d2$

Hence we change weights.

$\Delta w' = c.(d2 - O2) \cdot X2$

$$= 1(1 - -1) \cdot \begin{bmatrix} 0 \\ -1 \\ 2 \\ -1 \end{bmatrix} = \begin{bmatrix} 0 \\ -2 \\ 4 \\ -2 \end{bmatrix}$$

$W6 = W5 + \Delta w'$

$$= \begin{bmatrix} 1 \\ 6 \\ 0 \\ 3 \end{bmatrix} + \begin{bmatrix} 0 \\ -2 \\ 4 \\ -2 \end{bmatrix} = \begin{bmatrix} 1 \\ 4 \\ 4 \\ 1 \end{bmatrix}$$

Step3: $net3 = W6 \times X3$

$$= [1\ 4\ 4\ 1] \cdot \begin{bmatrix} -2 \\ 0 \\ -3 \\ -1 \end{bmatrix}$$

$net3 = -2\ 0 - 12\ -1 = -15$

$\therefore O3 = -1$

$\therefore O3 = d3 \therefore W7 = W6.$