S.C
M-4

FuZZY LOGIC → unclear

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* **Fuzzy logic :-** It is The term Fuzzy refers to things that are not clear or are vague. * The condition which don't have Dezire yes or No.

* Many situation we can't determine whether the state is true or false, their fuzzy logic provides very valuable flexibility for reasoning.

▷ In the boolean System, truth Value, 1.0 represents the absolute truth value and 0.0 represents the absolute 'false' value.

Note But, In fuzzy system, there is no logic for the absolute truth or false value.

▷ It contains only partially True and partially false

* Is it Cold? → Yes/1, → No/0] Boolean Logic

* Is it Cold? → Very Much/0.9 (changes), → Little/0.25, → very Less/0.1 → Fuzzy Logic → Mathematical language

Relational Logic + Boolean Logic + Predicate Logic ⇐ Mathematical language

↓

All combined Together → FUZZY LOGIC

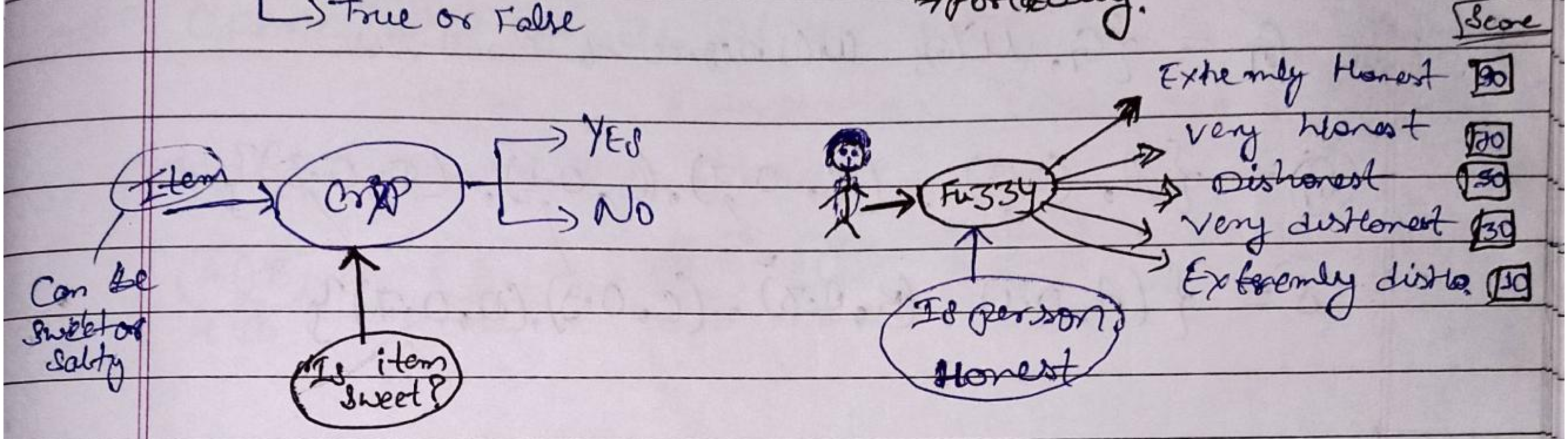
* Fuzzy logic deals with Fuzzy set / Fuzzy Algebra.

Crisp Logic Vs Fuzzy Logic

* Crisp Logic

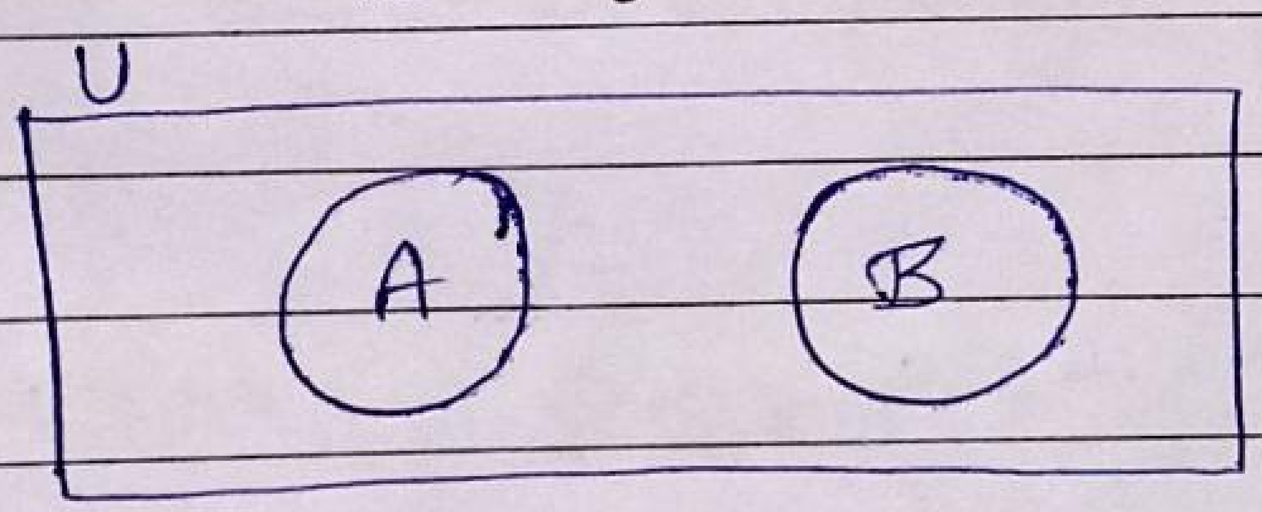
Crisp o/p
- → Yes or No
- → True or False

Fuzzy o/p
- → may be
- → may not be
- → Absolutely
- → partially.



* Crisp Set :-

U : All students
A : In 10th
B : In 12th



* In this Not a single individual who available in Both, & its is Crisp set (Yes or No).

→ An element only can belongs to one set, Not more than one.

(4).

Fuzzy Sets

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U: All students ; G: Good students.

S: Bad students.

Member-ship function $G = \{G, \mu(G)\}$ ($\mu()$ degree of Goodness.

$G = \{A, (0.9), (B, 0.7), (C, 0.1), (D, 0.3)\}$

$S = \{(A, 0.1), (B, 0.3), (C, 0.9), (D, 0.7)\}$

Note :- Member-ship value are ranging from 0 to 1 (Also Deci 0.2, 0.3

↳ If M.value = 0 then we Ignore that variable.

↳ Sets only cotain (0< values to =1). or element.

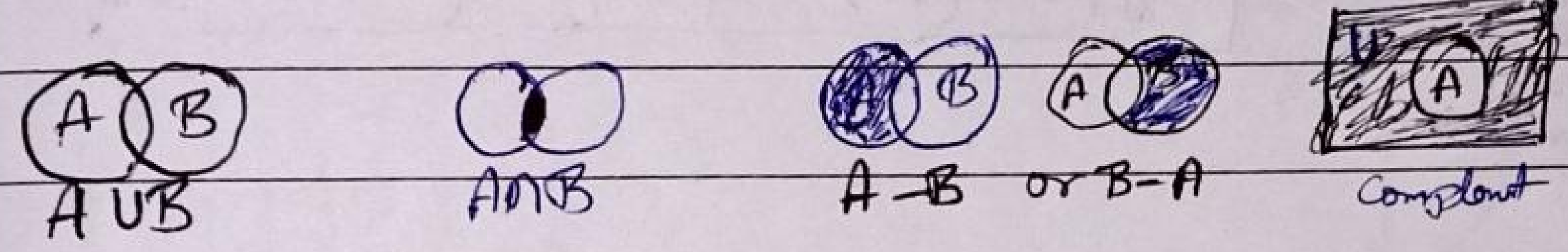
↳ IN this A element can present in two Sets.

*Classical Sets

- Classical set is a collection of distinct objects. Ex:- A set of students passing grade

Operations on Cl. set:-

Union, Intersection, Difference, Complement of set, Cartesian Product.



Property of classical set:-

1. Commulative property :- $\boxed{A \cup B = B \cup A}$, or $\boxed{A \cap B = B \cap A}$
2. Associative Property :- $\boxed{A \cup (B \cup C) = (A \cup B) \cup C}$, $\boxed{A \cap (B \cap C) = (A \cap B) \cap C}$
3. Distributive Property :- $\boxed{A \cup (B \cap C) = (A \cup B) \cap (A \cup C)}$
   $\boxed{A \cap (B \cup C) = (A \cap B) \cup (A \cap C)}$
4. Idempotency Property :- $\boxed{A \cup A = A}$ and $\boxed{A \cap A = A}$
5. Identity Property :- $\boxed{A \cup \varphi = A}$ $\boxed{A \cap X = A}$ $\boxed{A \cap \varphi = \varphi}$
   $\boxed{A \cup X = X}$
   X : Universal set
6. Transitive Property :- if $A \subseteq B \subseteq C$, then $A \subseteq C$
7. Involution " :- $\boxed{\bar{\bar{A}} = A}$
8. De Morgan's Law :- $\boxed{\overline{A \cap B} = \bar{A} \cup \bar{B}}$ $\boxed{\overline{A \cup B} = \bar{A} \cap \bar{B}}$

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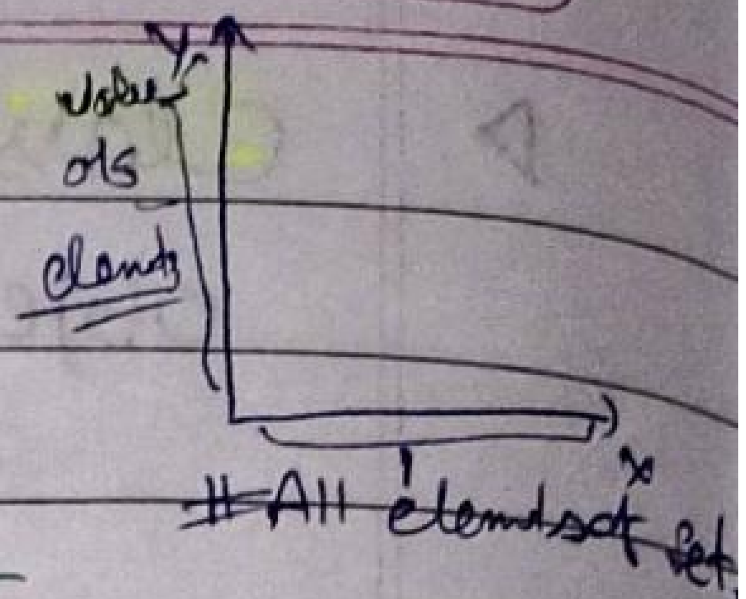
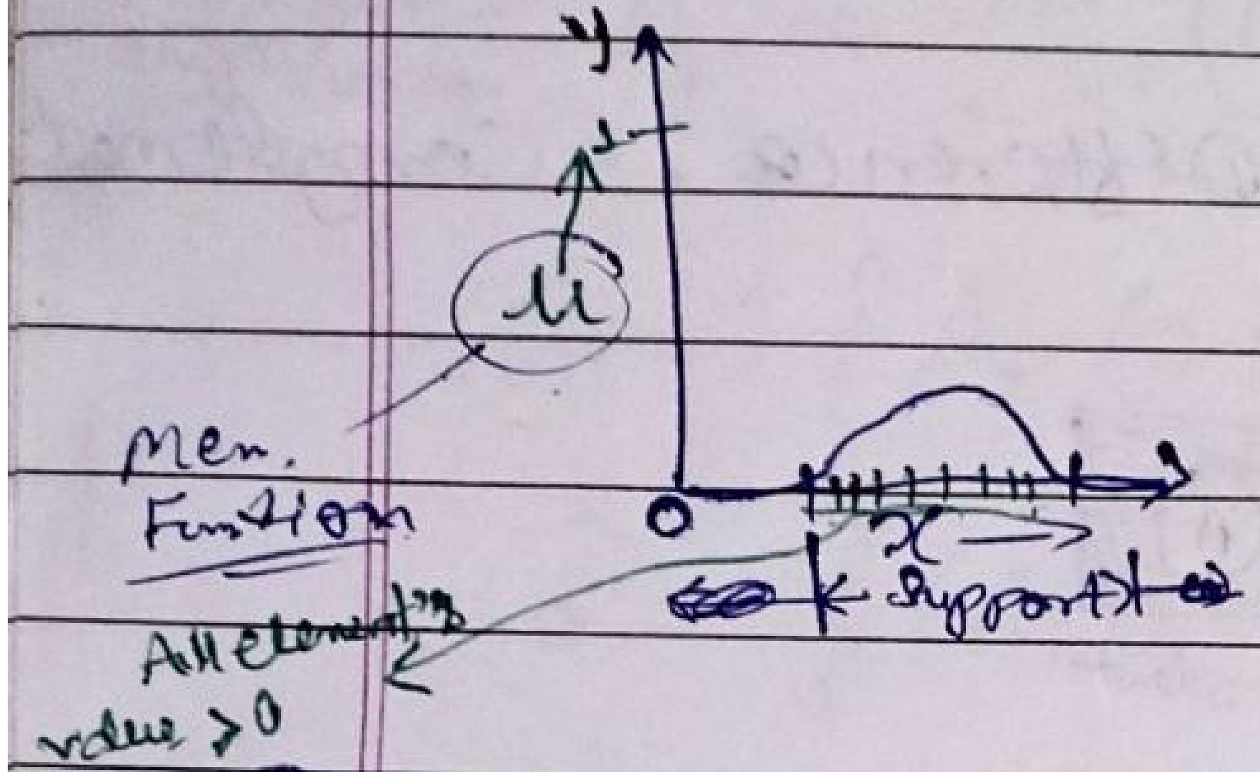
Features

MemBERship Function



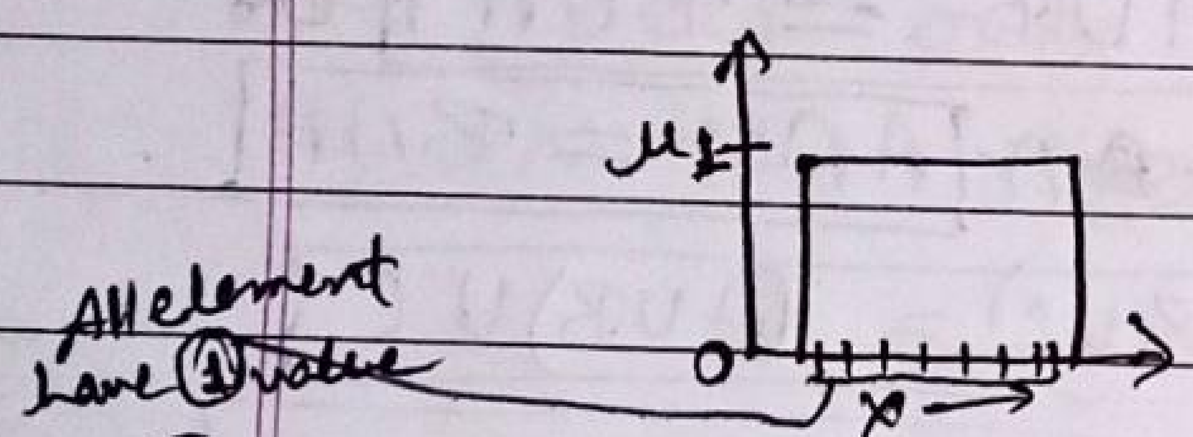
(I) **Support** :- 'Set' of All points such that $\{\mu_A(x) > 0\}$



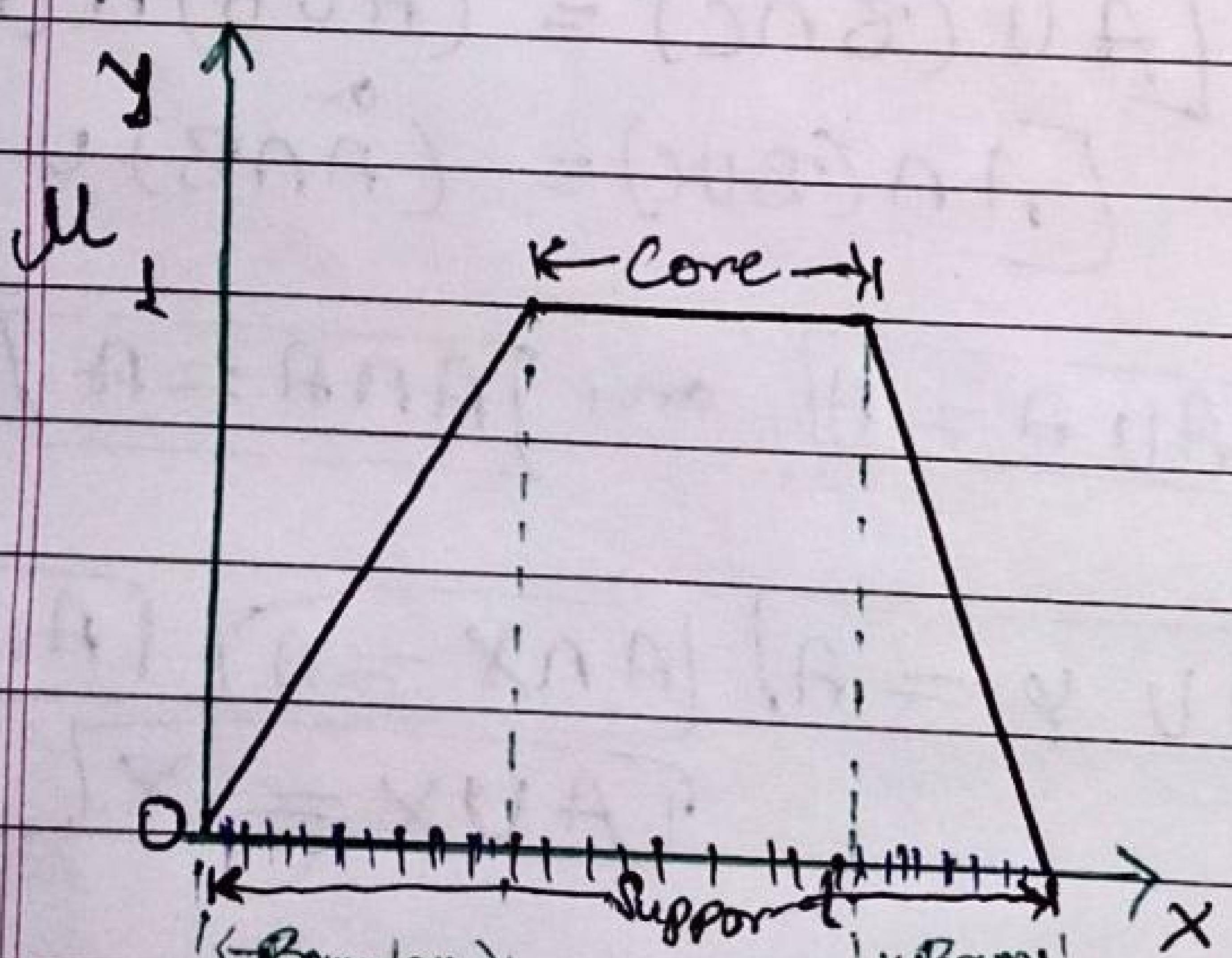
$$\boxed{Support(A) = \{x \mid \mu_A(x) > 0\}}$$

(II) **Core** :- $\boxed{\mu_A(x) = 1}$

$$\boxed{Core(A) = \{X \mid \mu_A(x) = 1\}}$$



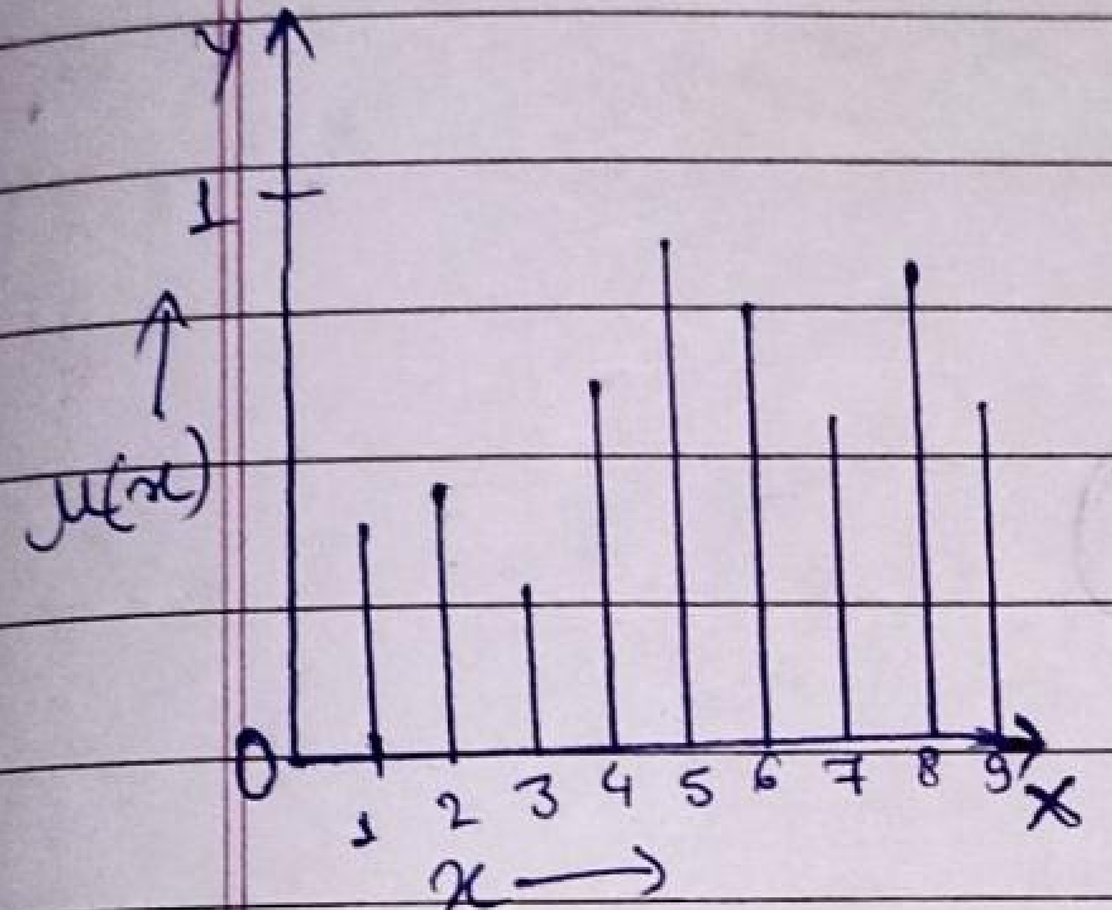
(III) **Boundary** :- $(1 > \mu_A(x) > 0)$



Note * Those element who belongs to core, Never belongs to boundary

Membership Function

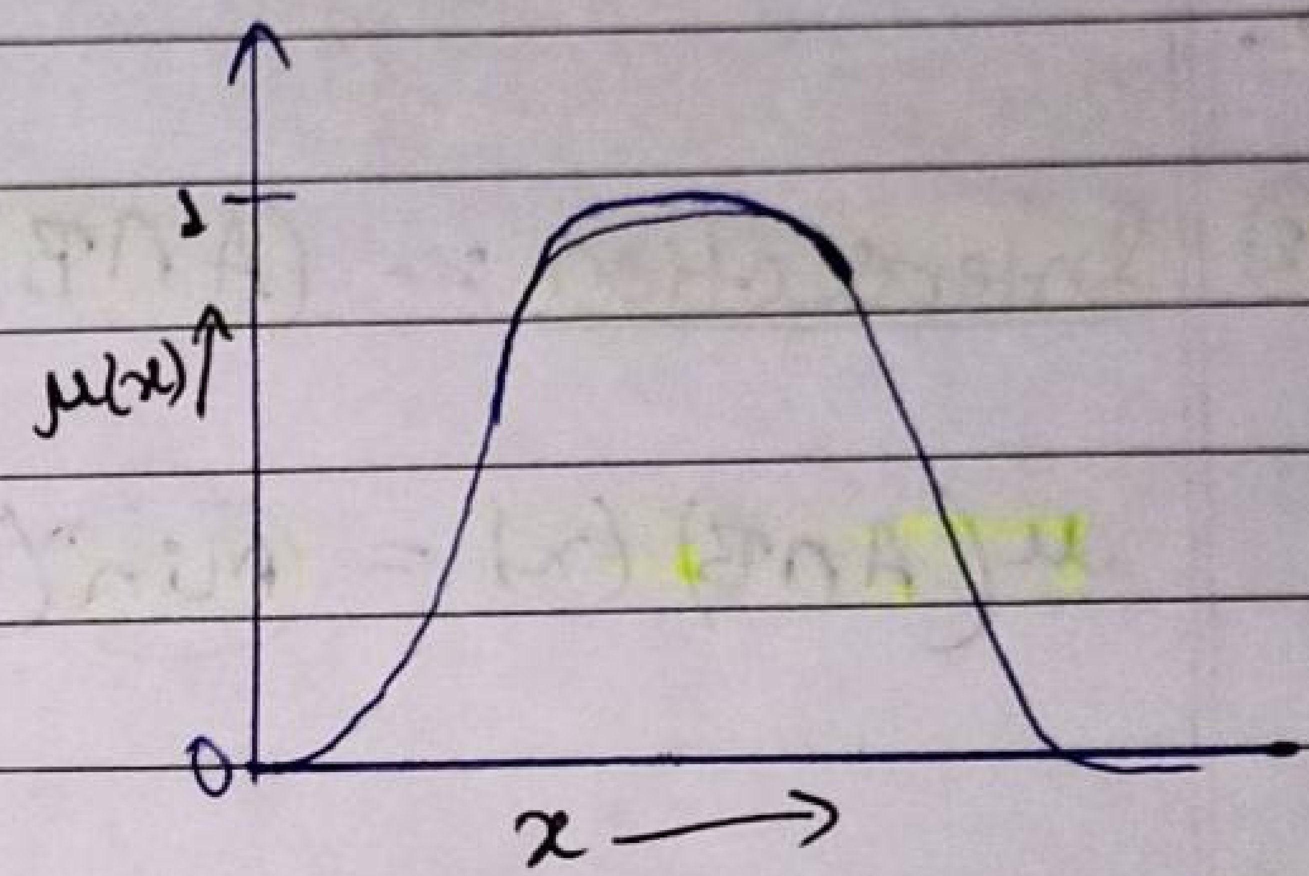
* Discrete M.F :-



① If both x & μ(x) are discrete then follow this M.F ↑.

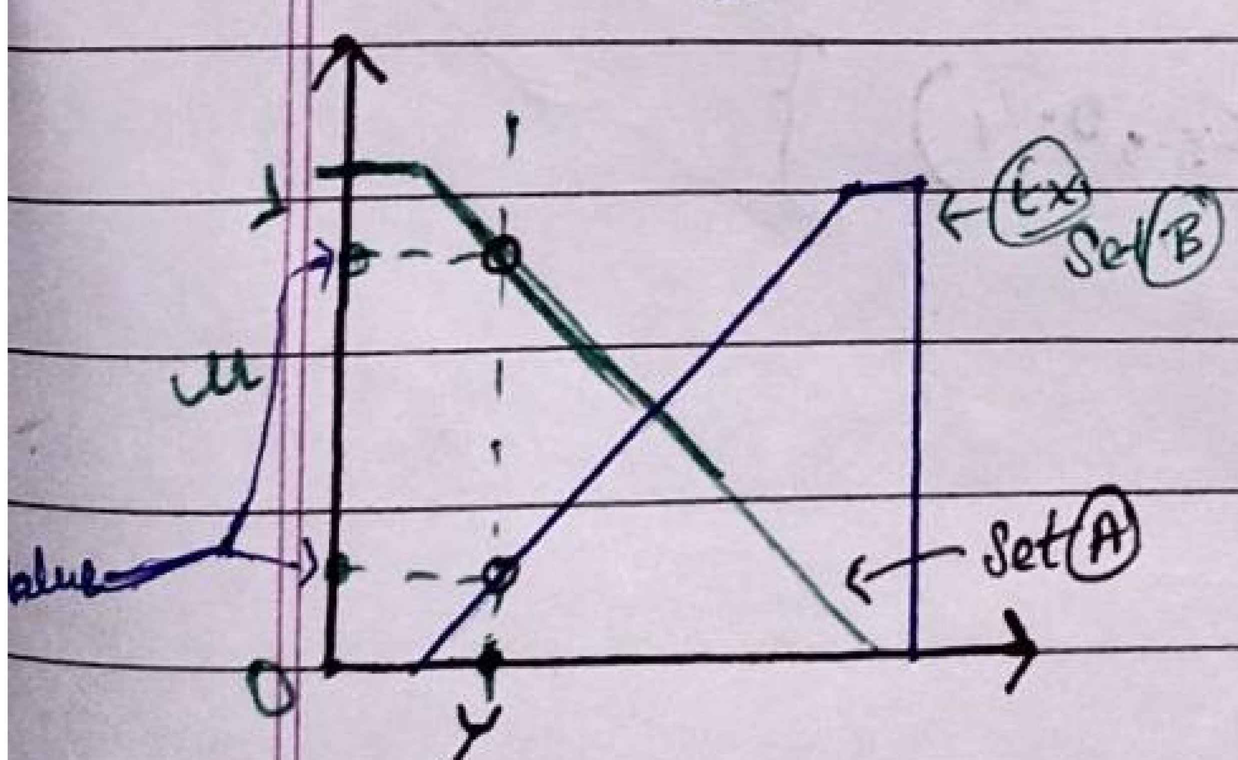
② if x or μ(x) are discrete then also follow D. MF.

* Continuous MF :-



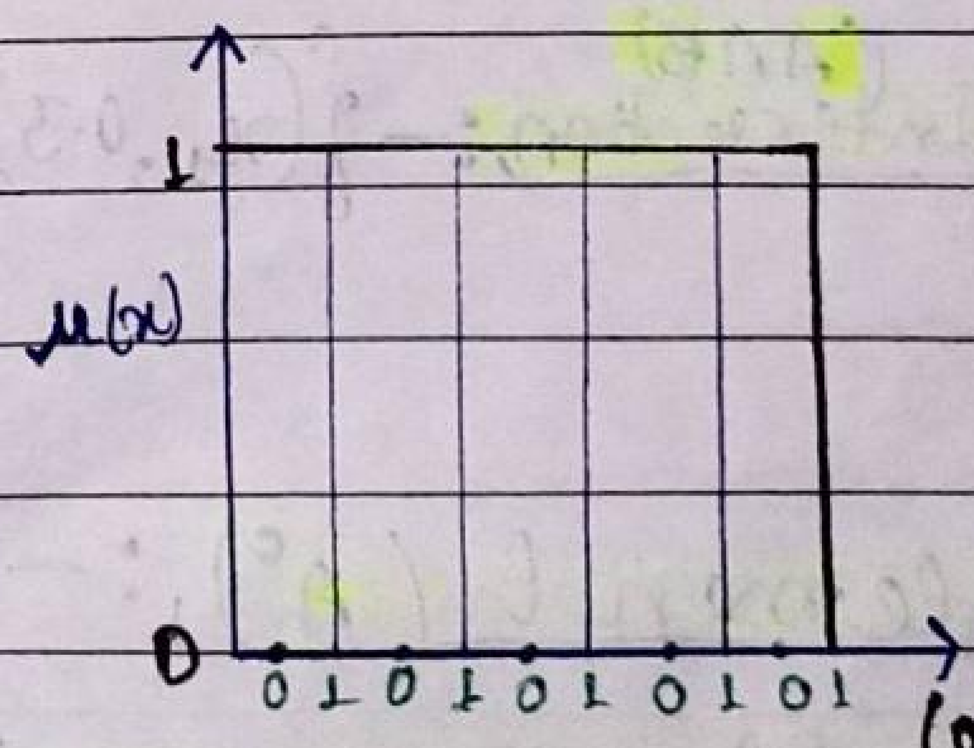
① If x & μ(x) both continious, ② if x or μ(x) continious ③ if any one or (both) is continious then use this f(x)

* Fuzzy set :-



This element intersecting two points. So this elements belongs to A & B Both with 'different value'.

* Crisp set :-



(only '0' or '1' possible)

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$m = 4$

Fuzzy Set Operation

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(1) Union :- $(A \cup B)$

* To get membership value. $\mu_{(A \cup B)}(x) = \text{Max}(\mu_A(x), \mu_B(x))$:- Formula to get mem. value

(2) Intersection :- $(A \cap B)$

$$\mu(A \cap B)(x) = \text{Min}(\mu_A(x), \mu_B(x))$$

Note:- In fuzzy set operation elements will remain same as Normal set (union, Intersection etc.) But, only mem. value ($\mu(x)$) are taken according to formula.

Δ Example:- Two sets are assumed -

$$A = \{(x_1, 0.6), (x_2, 0.7), (x_3, 0.4)\}$$
$$B = \{(x_1, 0.3), (x_2, 0.2), (x_3, 0.5)\}$$

(A) Fuzzy Union $(A \cup B)$:- $\{(x_1, 0.6), (x_2, 0.7), (x_3, 0.5)\}$

(B) Fuzzy Intersection $(A \cap B)$:- $\{(x_1, 0.3), (x_2, 0.2), (x_3, 0.4)\}$

(3) Complement (A^c) :-

$$\boxed{\mu(A^c)(x) = 1 - \mu_A(x)}$$

used Above set

EX:- Fuzzy $A^c = \{(x_1, 0.4), (x_2, 0.3), (x_3, 0.6)\}$ $(1 - \mu(x))$

Fuzzy $B^c = \{(x_1, 0.7), (x_2, 0.8), (x_3, 0.5)\}$

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(4) Vector product (A·B) :-

$$\boxed{\mu_{A \cdot B}(x) = \mu_A(x) \cdot \mu_B(x)}$$

(5) Scalar Product ($\alpha \times A$)

$$\boxed{\mu_{\alpha A}(x) = \alpha \times \mu_A(x)}$$

(6) Equility :- (A=B)

$$\boxed{\mu_A(x) = \mu_B(x)}$$

(7) Power (A^α)

$$\boxed{\mu_{A^\alpha}(x) = (\mu_A(x))^\alpha}$$

Ex:- $A = \{(x_1, 0.6), (x_2, 0.7), (x_3, 0.4)\}$
$B = \{(x_1, 0.3), (x_2, 0.2), (x_3, 0.5)\}$

∞ Fuzzy Vector product (A·B) :- $\{(x_1, 0.18), (x_2, 0.14), (x_3, 0.20)\}$ $(x_1^A \times x_1^B)$

∞ Scalar product ($\alpha \times A$) :- $\{(x_1, 0.6), (x_2, 0.7), (x_3, 0.4)\}$

$\boxed{\alpha}$
Range is 0 to 1
including (0,1)
we Assumed (0-1), $x_1 = (x_1 \times \alpha)$

∞ Equility (A=B) :- $A(x_1) \neq B(x_1)$ (example)

∞ Power (A^α)

$1 \leq \alpha \geq 0$ {if α is less than 1,
(1) its called as 'Dilution'}

(2) if α is greater than 1,
its called 'Con'

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Combination of Operation

ADVANCED operators.

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(VIII) Sum (A+B) :-

$$\left[\mu_{A+B}(x) = \mu_A(x) + \mu_B(x) - \underbrace{\mu_A(x)\cdot\mu_B(x)}_{\text{Vector product}}\right]$$

(IX) Difference (A−B) :-

$$\boxed{\mu_{A-B}(x) = \mu_{A\cap B^c}(x)}$$

[Compliment + Intersection]

① ②

(X) Disjunctive sum (A ⊕ B) $\boxed{\text{XOR}}$

$$\left[\mu_{(A\oplus B)}(x) = (A^c \cap B) \cup (A \cap B^c)\right]$$

① ② ③ ② ①

(XI) Cartesian Product :- (A × B)

$$\left[\mu_{A\times B}(x,y) = \min\left(\mu_A(x), \mu_B(y)\right)\right]$$

* Example :-

$$A(x) = \{(x_1, 0.2), (x_2, 0.3), (x_3, 0.5)\}$$
$$B(y) = \{(y_1, 0.8), (y_2, 0.6), (y_3, 0.3)\}$$

→ Fuzzy Cartesian (A×B) :-

$$\begin{array}{c|ccc} & y_1 & y_2 & y_3 \\ \hline x_1 & 0.2 & 0.2 & 0.2 \\ x_2 & 0.3 & 0.3 & 0.3 \\ x_3 & 0.5 & 0.5 & 0.3 \end{array}$$

Fuzzy Set Properties

* ** These all is followed by Fuzzy set :-

(I) Commulative :- $\boxed{A \cap B = B \cap A}$; $\boxed{B \cup A = A \cup B}$

(II) Associative :- $\boxed{A \cup (B \cup C) = (A \cup B) \cup C}$; $\boxed{A \cap (B \cap C) = (A \cap B) \cap C}$

(III) Distributive :- $\boxed{A \cup (B \cap C) = (A \cup B) \cap (A \cup C)}$; $\boxed{A \cap (B \cup C) = (A \cap B) \cup (A \cap C)}$

(IV) Idempontence :- $\boxed{A \cup A = A}$; $\boxed{A \cap A = \phi \text{(null)}}$; $\boxed{A \cup \phi = A}$; $\boxed{A \cap \phi = \phi}$

(V) Transitive :- If $\boxed{A \subseteq B \;;\; B \subseteq C \text{ the } A \subseteq C}$

Proper subset/equal

(VI) Demorgan's law :- $\boxed{(A \cap B)^c = A^c \cup B^c}$; $\boxed{(A \cup B)^c = A^c \cap B^c}$

* Crisp Relation :- Also known as classical.

Ex:- $A = \{1, 2, 3\}$; $B = \{4, 7, 8\}$

$A \times B = \{(1,4), (1,7), (1,8), (2,4), (2,7), (2,8), (3,4), (3,7), (3,8)\}$

$$R = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{array}{ccc} 4 & 7 & 8 \end{array} \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \end{array}$$

$R = \{(1,4), (2,7), (3,8)\}$

$R_1 = \boxed{\{(a,b) \mid a < b, (a,b) \in A \times B\}}$

$R_1 = \{(1,4), (1,7), (1,8), (2,4), (2,7), (2,8), (3,7) (3,8), (3,4)\}$

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Operation on Crisp/classic

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I Union $(A \cup B)$:-

- We choose 'Max' value of any particular position (a_{11} & b_{11}) if ($a_{11} > b_{11}$) we choose $\boxed{a_{11}}$ value.

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix} \qquad B = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\boxed{A \cup B} = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix}$$

II Intersection $(A \cap B)$:-

- Here, we choose the 'MIN' value of compared two elements ~~of~~ in a particular sets. ($a_{11} > b_{11}$), $\boxed{b_{11}}$ will be choosed.

$$\boxed{A \cap B} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

III Compliment (A^c) :-

- Just compliment of the elements. $(0)^c = (1)$, $1^c = 0$.

$$\boxed{A^c} = \begin{bmatrix} 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 \end{bmatrix}$$

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Fuzzy If-then Rule

Known as →
* Fuzzy Implication
* Fuzzy Rule
* Fuzzy Conditional Statement

$\boxed{\text{If } x \text{ is } A, \text{ then } y \text{ is } B}$

* It Makes or Establish the Relation b/w two 'preposition'

- x is 'A' :- called as Antecedent or premise
- y is 'B' :- called as Consequence or conclusion

Fuzzy Rule 'R' denoted as $R: A \rightarrow B$
Implicate Symbol.

∞ Representation of Relation is ('best way') :- [Matrix]

Example :-
IF Temp is high — (Premise)
then pressure is LOW — (conclusion).

Rule → $R: T_{HIGH} \rightarrow P_{LOW}$

$T_{HIGH} = \{(25, 0.1), (30, 0.2), (35, 0.5), (40, 0.6)\}$

$P_{LOW} = \{(2, 0.3), (5, 0.5), (6, 0.4)\}$

All cells represents the Straigth value

$$R: A \rightarrow B \quad R = (A \times B) = \begin{array}{c|ccc} & 2 & 5 & 6 \\ \hline 25 & 0.1 & 0.1 & 0.1 \\ 30 & 0.2 & 0.2 & 0.2 \\ 35 & 0.3 & 0.5 & 0.4 \\ 40 & 0.3 & 0.5 & 0.4 \end{array}$$

Note → To represent the relation b/w Two sets, best way is Matrix by using 'Cartesion product' $(A \times B)$ = of both sets.

Fuzzification
De - fuzzification

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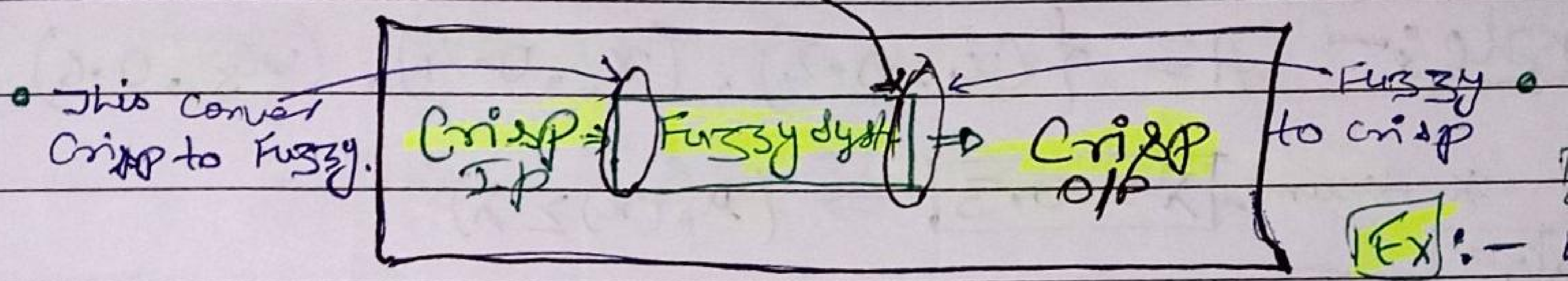
* **Fuzzyfication :-** To the convert the crisp into fuzzy is called fuzzifi.

I/p
Crisp ⇒ [Fuzzification] ⇒ o/p Fuzzy.

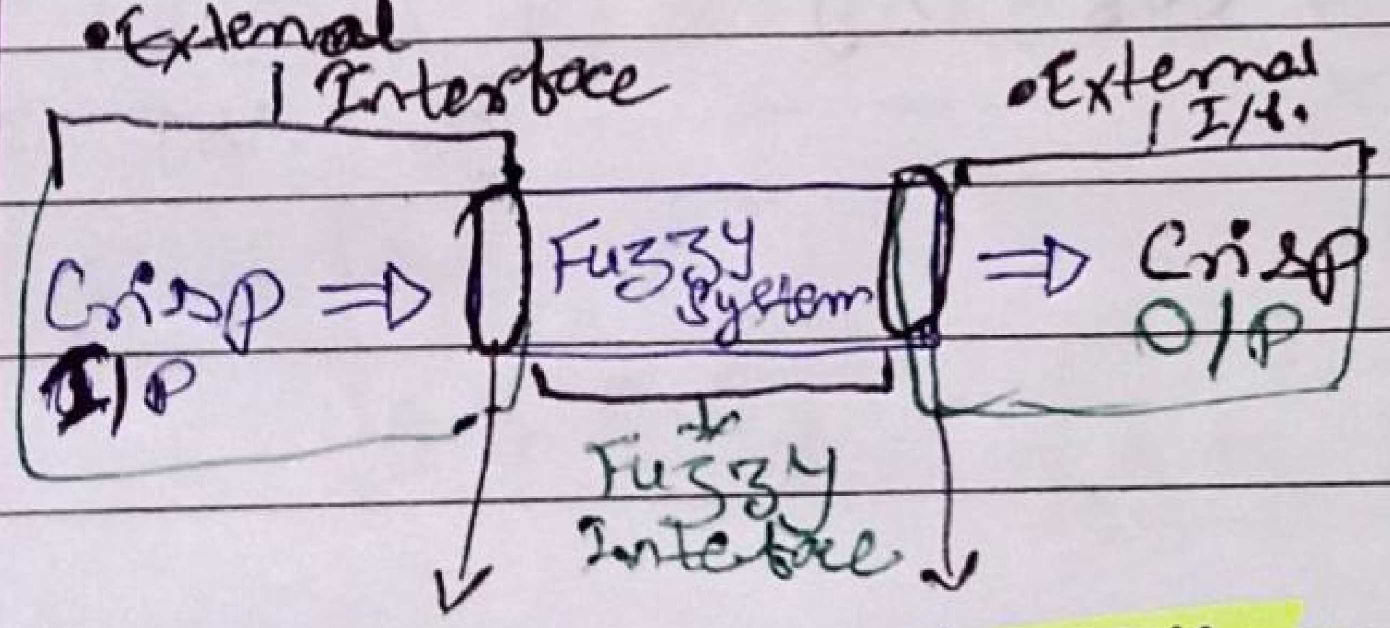
▷ **De-fuzzification :-** Fuzzy to crisp Conversion.



Why needed this method

Ex :- We code Regularly and gives the input in Highlevel Language, but Machine don't understand it, So by help of Compiler it change [HLL to LL] & execution the program And at end again Compiler change that [LL to HLL] ~~this~~ Because we don't Understand Machine Language. Same this applied in Fuzzy.

1). Lambda - Cut Method
2). Maxima - Method.
3). Weighted Sum Method
4). Centroid Method



* Fuzzy fire * defuzzy fire.

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M=4

① Lamda - Cut method (Fuzzy) sets

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- Fuzzy sets to Crisp set.

- Fuzzy set (A) $\xrightarrow{To}$ Crisp set. $(A\lambda)$ $(0 \leq \lambda \leq 1)$

Representation of Crisp set

element/variable

- $\underbrace{A\lambda}_{\text{Crisp set}} = \{ x \mid \overbrace{\mu_A(x) \geq \lambda}^{\text{must satisfy by }(x)} \}$

The element who belongs to Crips (A)

Example:- $A = \{(x_1, 0.2), (x_2, 0.4), (x_3, 0.6)\}$

* Assumed $\boxed{\lambda = 0.3}$ $\Rightarrow (\mu_A(x) \geq \lambda)$

* $\boxed{x_1 (0.2 \geq \lambda 0.3)}$
Not satisfy
$\boxed{\text{'0' put. else '1'}}$

$A_{0.3} = \{(x_1, 0), (x_2, 1), (x_3, 1)\} = \boxed{\{x_2, x_3\}}$

x_1 doesn't belongs to A set.

Crisp set - of
'1' contain element will be select

$B = \{(y_1, 0.5), (y_2, 0.4), (y_3, 0.7)\}$.

$B_{0.7} = \{(y_1, 0), (y_2, 0), (y_3, 1)\} = \boxed{\{y_3\}}$

(B) crisp set.

λ value For this example

① Lamda Cut For

X Fuzzy rel. → Crisp relation X

crisp value

- Fuzzy set A $\xrightarrow{\text{to}}$ Crisp set $A\lambda$ $(0 \le \lambda \le 1)$.

membership value of (x).

- $A\lambda = \{x \mid \mu_A(x) \ge \lambda\}$

*Crisp set.

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∞ Examples—

$\boxed{A} = \{(x_1, 0.2), (x_2, 0.4), (x_3, 0.6)\}$.

Taken :— $\boxed{\lambda = 0.3}$

$\boxed{A_{0.3}} = \{(x_1, 0), (x_2, 1), (x_3, 1)\} = \{x_2, x_3\}$

$\boxed{B} = \{(y_1, 0.5), (y_2, 0.4), (y_3, 0.7)\}$

Assumed for (B) set $B_{0.7} = \{(y_1, 0), (y_2, 0)$

Lamda — Cut Method (Fuzzy Relation)

(Fuzzy Relation $\xrightarrow{\text{to}}$ Crisp relation

- $R = \begin{bmatrix} 0.2 & 1 \\ 0.3 & 0.6 \end{bmatrix}$ $\boxed{\lambda = 1, 0.5, 0.1, 0}$

* Crisp Relation depends on 'λ' (lamda)

Consider $\boxed{\lambda = 1}$

$R_1 = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}$, $R_{0.5} = \begin{bmatrix} 0 & 1 \\ 0 & 1 \end{bmatrix}$, $R_{0.1} = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$

$R_0 = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$

Sc: $M = x^4$

② Maxima Methods

→ Height of fuzzy set.

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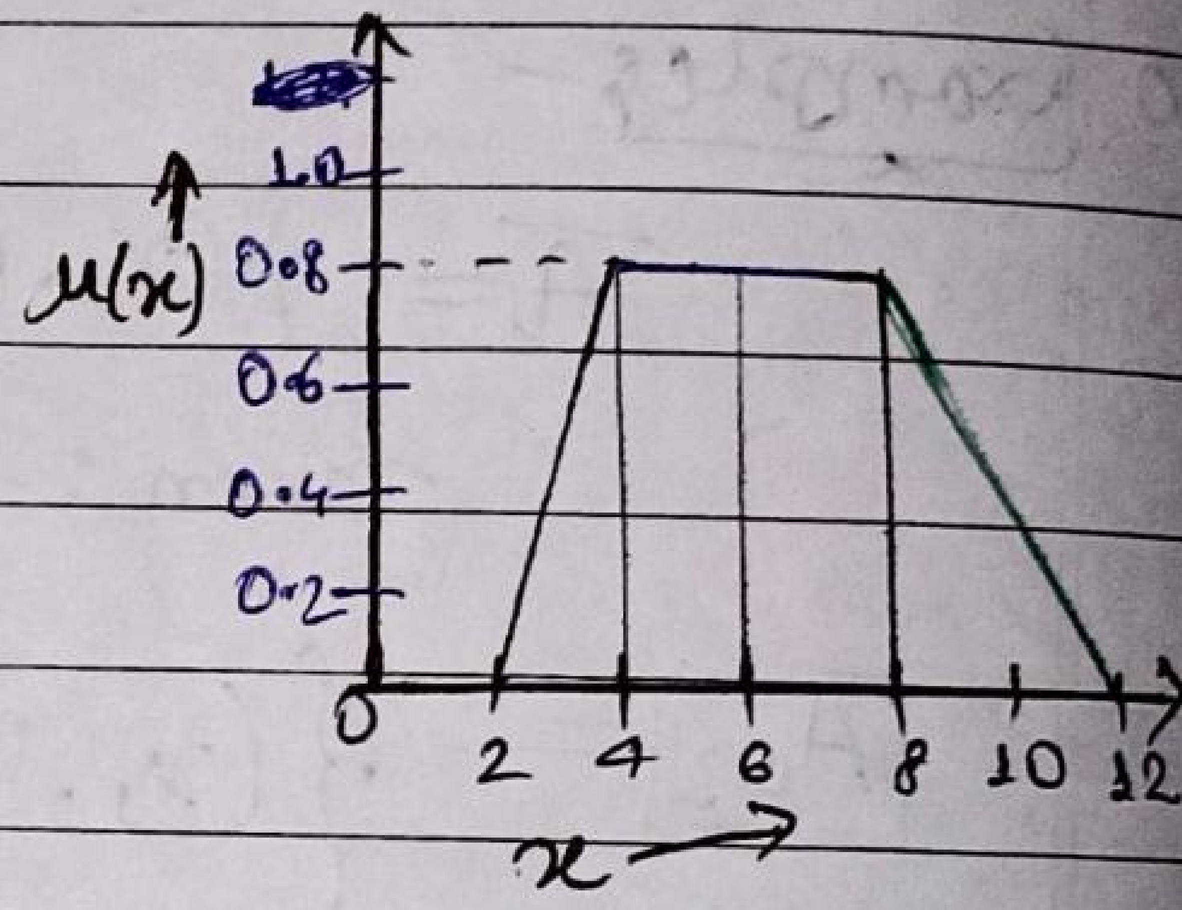
* Crisp value Denotes Here, by (x^*).

(I) First of Maxima (FOM) :-
(II) Last of Maxima (LOM) :-
(III) Mean of Maxima (MOM) :-

▷ ** Maxima :- is a 'Height of Fuzzy set'



(I) FOM :- Just observe the Graph :-
& take first Max element :-

$$\boxed{x^* = 4}$$

↳ * Height is [0.8]

(II) LOM :- Just observe the Graph &
take Last 'Max' element :-

Max = (4, 6, 8) *According to example

$$\boxed{x^* = 8}$$

(III) MOM :- Just find the 'mean' of
maximum elements,

$$\boxed{x^* = \frac{\sum x_i \in M \, x_i}{|M|}}$$

$x = 4, 6, 8$

$M = \{ x \mid \mu_A(x) = \text{height of fuzzy set} \}$

$$\boxed{x^* = \frac{4+6+8}{3}} = \boxed{6} \text{ A}$$

$|M|$ = Cardinality of set M.

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De-fuzzification.

③ Weighted Average Method

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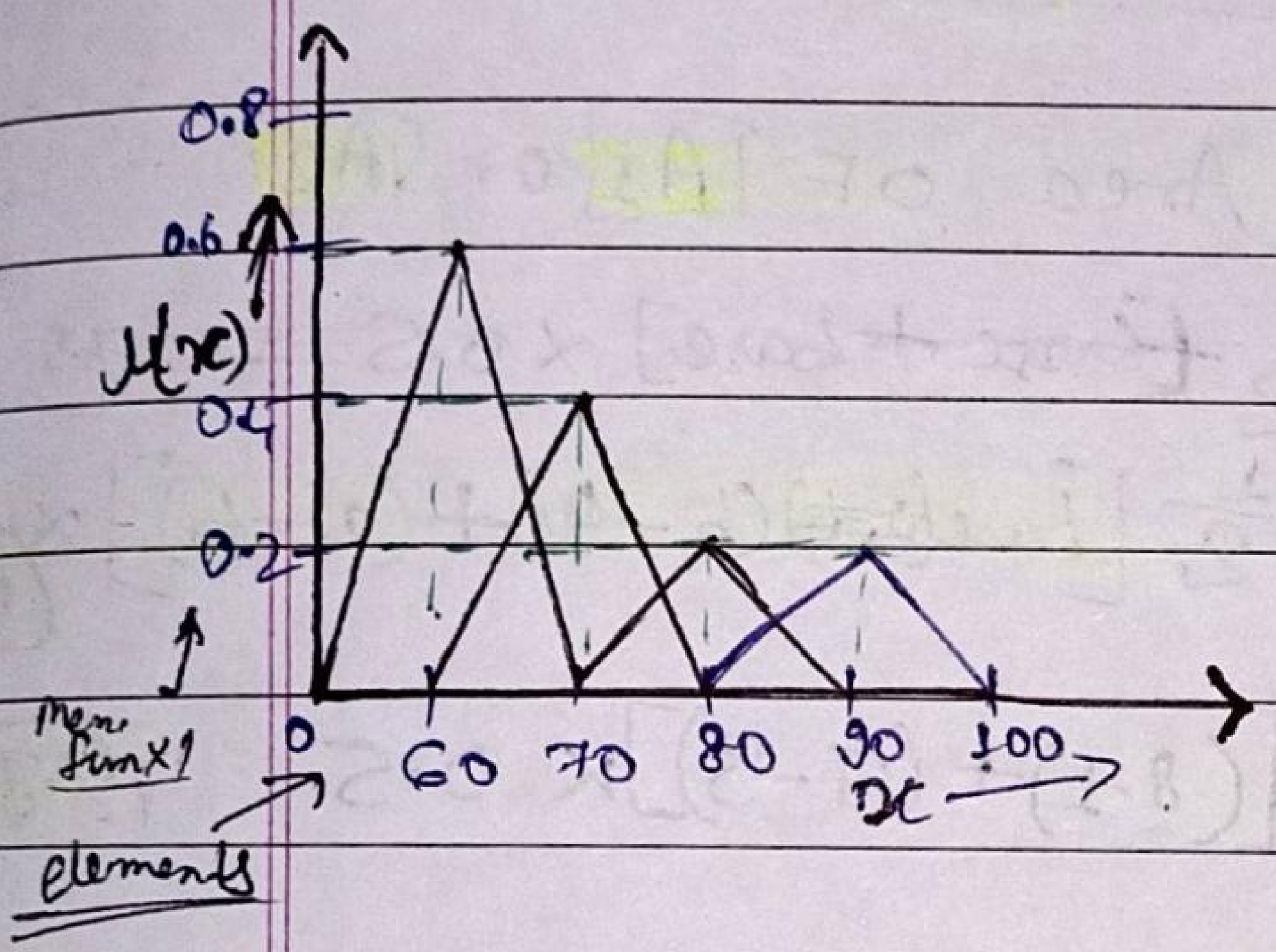
$$\boxed{x^* = \frac{\sum \mu(x) \cdot x}{\sum \mu(x)}}$$



$$x^* = \frac{(60 \times 0.6) + 70 \times 0.4 + 80 \times 0.2 + 90 \times 0.20}{0.6 + 0.4 + 0.2 + 0.2}$$

$$\boxed{x^* = 70}$$

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Defuzzification

(4) Centroid Method

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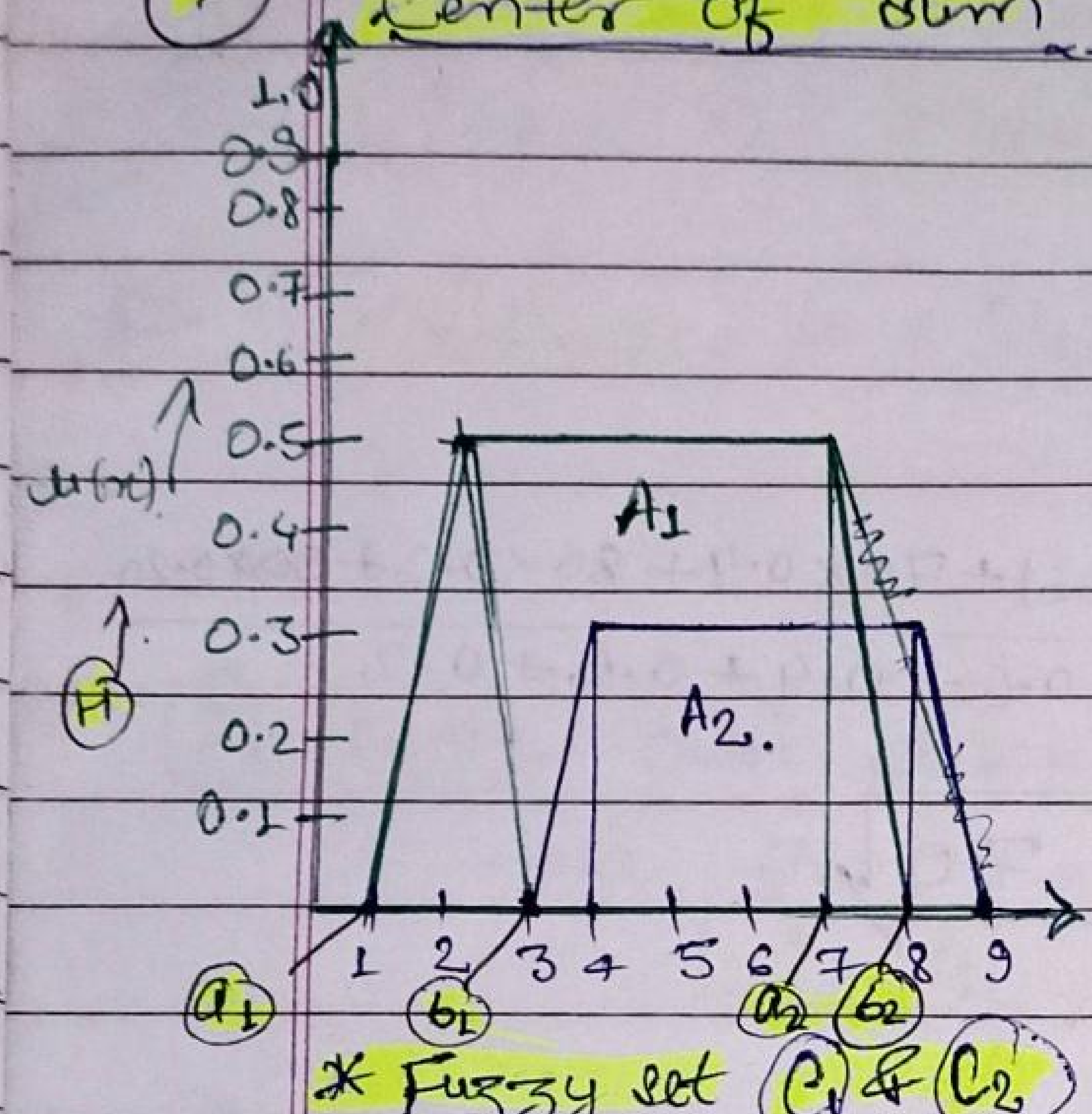
(I) Center of Sum (COS):-



* Fuzzy set C1 & C2

$$\boxed{x^* = \frac{\sum A_{(i)} x_c}{\sum A}}$$

* To Find Area OF $\boxed{A_1}$ or $\boxed{A_2}$

$A_1 = \frac{1}{2}$ ~~[base +~~ base] × ~~0.5 = 2.75~~

$\boxed{A_1} = \frac{1}{2}$ [base ~~(a+b)~~ $(b_2 - a_1) + (a_2 - b_1)$] ×

$= \frac{1}{2}[(8-1)+(7-3)] \times 0.5 = \boxed{2.75}$

$\boxed{A_2} = \frac{1}{2}[(9-3)+(8-4)] \times 0.3 = \boxed{1.5}$

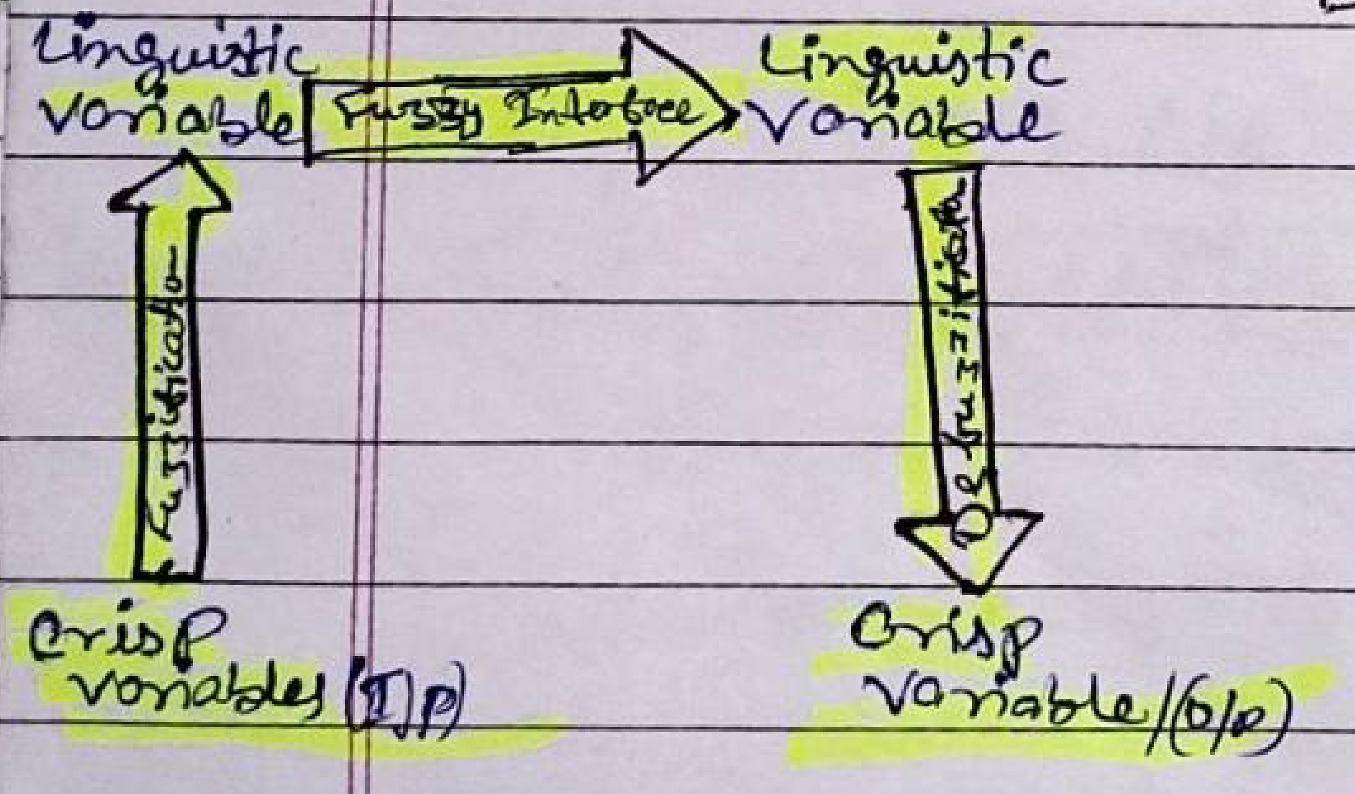
$$x^* = \frac{A_1 \cdot x_{c_1} + A_2 \cdot x_{c_2}}{A_1 + A_2}$$

Center element of C1

Center of C2

$$= \frac{2.75 \times 5 + 1.50 \times 6}{2.75 + 1.5}$$

$$\boxed{x^* = 5.35}$$



(II) Center of Gravity :- (COG) :-

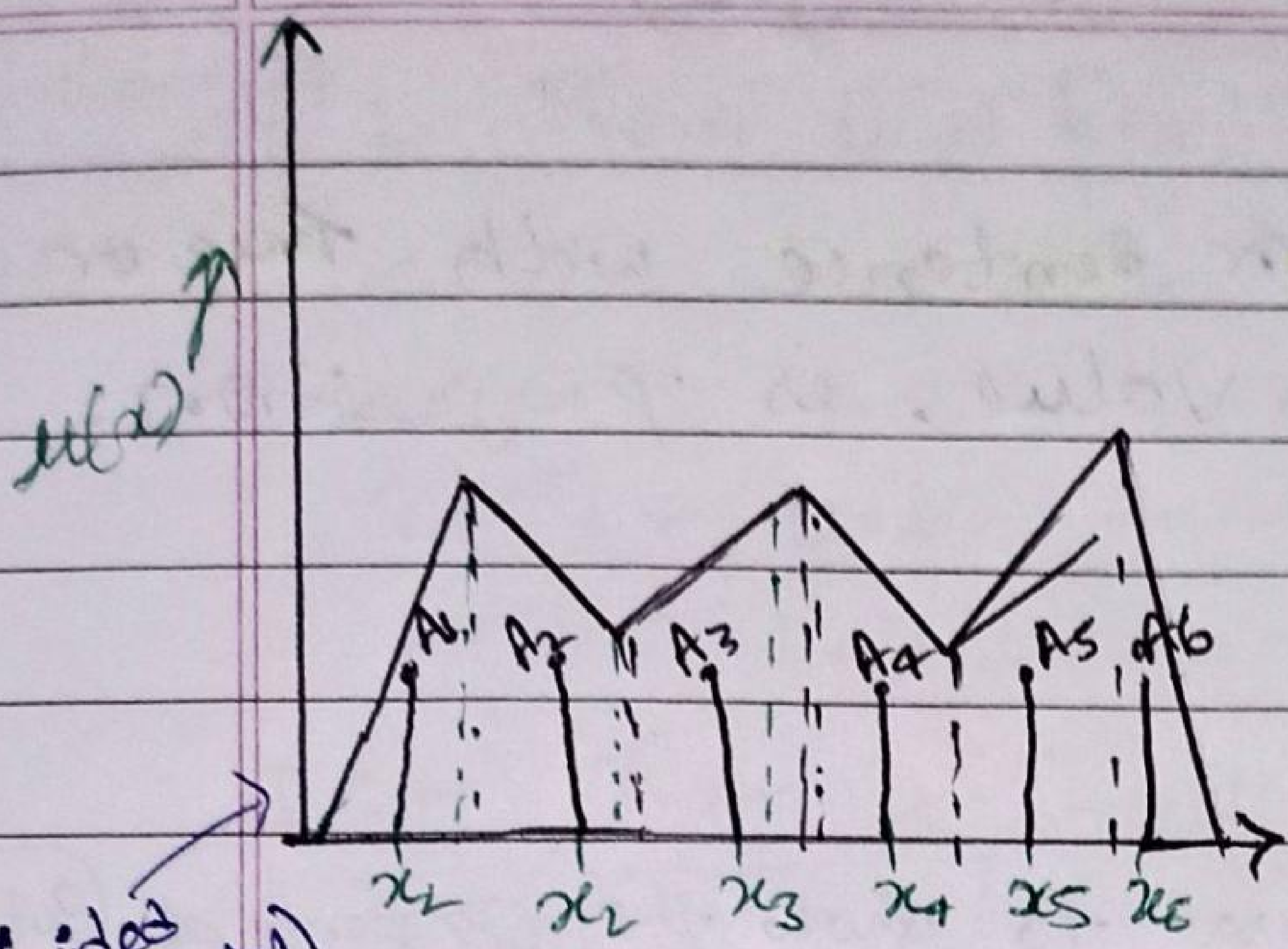
1st step :- partition & (2) Get Area of each (A_i to n) (3) Apply formula

(3) COG of each element:

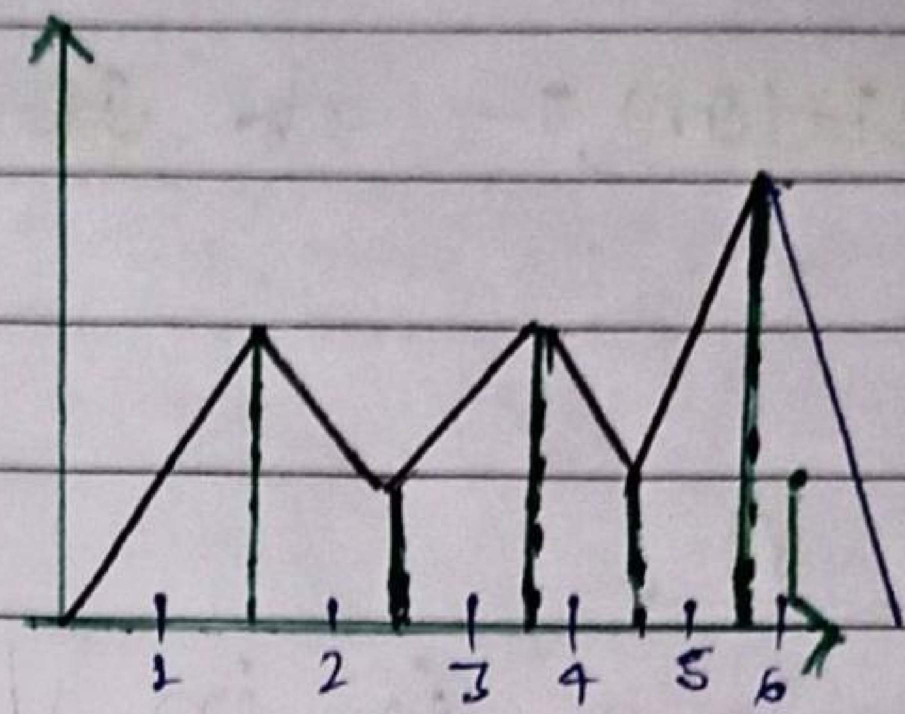
$$x^* = \frac{\sum_{i=1}^{n} x_i \cdot \mu(x_i)}{\sum_{i=1}^{n} \mu(x_i)}$$

$$\boxed{x^* = \frac{\sum_{i=1}^{n} x_i A_i}{\sum_{i=1}^{n} A_i}}$$

COG



(Divided with dotted line)



⇒ Total '6' Positioned

$$X^* = \frac{\sum_{i=1}^{n} x_i \cdot A_i}{\sum_{i=1}^{n} A_i}$$

x_i = ith Position of COG.

A_i = Area of ith Position.

Truth Value of Tables in Fuzzy logic

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* **Proposition :-** A statement, or sentence with True or false value. is proposition.

o X is A.

⇒ "London is in UK."

London → Subject

UK → Predicate used to show the property of Subject

\# Truth Table Defines logic function of 2 propositions

1. Conjuction ($\wedge$) : X AND Y
2. Disjunction ($\vee$) : X OR Y
3. Implication ($\rightarrow$) : If X then Y
4. Bi-Directional ($\leftrightarrow$) : X IFF Y

IFF → 'If and only if'

o Truth value of proposition in fuzzy logic are in range [0, 1] - 0.1, 0.2 .. 1.

Eg :- P : Ram is Boy.

$\boxed{T(P) = 0.8}$

Truth value

▷ $T(x \text{ AND } y) = T(x) \wedge T(y) = \min[T(x), T(y)]$

▷ $T(X \text{ OR } Y) = T(x) \vee T(Y) = \max[T(x), T(y)]$

▷ $T(\text{NOT } X) = 1 - T(x)$

▷ $T(X \rightarrow Y) = T(X) \rightarrow T(Y) = \max[1 - T(X), \min[T(X), T(Y)]]$

(5) Fuzzy Proposition — Crisp Proposition

P : Ram is a boy.

* only True or false in crisp

$T(P) = 0.0$ — Abs. False
$T(P) = 0.2$ — partially False
$T(P) = 0.8$ — Partially True
$T(P) = 1.0$ — Abs. True

Q :- Ram is Intelligent

$\boxed{T(Q) = 0.6}$

⇒ Ram is Not Intelligent

$T(\bar{Q}) = 1 - T(Q) = 0.4$

⇒ Ram is Boy (and) So is Intelligent

$T(P \wedge Q) = \min(T(P), T(Q))$
$= \min(0.8, 0.6)$
$\boxed{= 0.6}$

- Fuzzy predicates :- (Shivram is Tall) — Fuzzy Predicate, Because Not mention (5 ft, 4 ft ...)
  (tall, short, quick)

- Fuzzy Predicate Modifier :- "Clighate is slightly shinny."
  (very, fairly, moderately, rather, slightly)

- Fuzzy Quantifiers :- "Many element is greater than ..."
  (Most, several, Many)

- Fuzzy Qualifiers :-
  ↳ Based on Truth (x ist)
  ↳ Based on probability (x is λ) Probability
  ↳ Based on possibility (x is π) Possibility

8c

Decompisition OF Rules

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(I) Multiple Cojunctive Antecedents:-

If x is $A_1, A_2, A_3 \ldots A_n$ Then Y is B_m

$A_m = A_1 \cap A_2 \cap A_3 \cap \ldots \cap A_n$.

$\rightarrow \mu_{A_m}(x) = \min[\mu_{A_1}(x), \mu_{A_2}(x), \ldots \mu_{A_n}(x)]$

$\Rightarrow$ $\boxed{\text{If } A_m \text{ then } B_m}$

(II) Multiple disjunctive Antecedent:-

If x is $A_1, A_2, A_3, \ldots A_n$ They Y is B_m

$A_m = A_1 \cup A_2 \cup A_3 \cup \ldots \cup A_n$

$\mu_{A_m}(x) = \max[\mu_{A_1}(x), \mu_{A_2}(x) \ldots \mu_{A_n}(x)]$

(III) Conditional Statements:-

If A_1 then B_1 Else B_2.

$\Rightarrow$ If A_1 then B_1
OR
If NOT A_1 then B_2.

(IV) Nested If-then rules:- (use AND, at most cases)

If A_1 Then [If A_2 then B_1]

$\Rightarrow$ If A_1 AND A_2 Then B_1

Aggregation Of Fuzzy Rule

(I) 'Conjunctive' System of Rules :-

- Rules to be jointly satisfied.
- Using AND (Bcos it True when both I/p true).
- Using Intersection.

Aggregate output

$y = y_1$ AND y_2 AND $y_3 \ldots\ldots$ AND y_n.

(OR)

$y = y_1 \cap y_2 \cap y_3 \ldots\ldots \cap y_n$

To calculate member-ship function

$$\mu_y(y) = \min\left[\mu_{y_1}(y), \mu_{y_2}(y), \mu_{y_3}(y) \ldots \mu_{y_n}(y)\right]$$

(II) 'Disjunction' System OF Rule :-

- The satisfaction of at least one Rule (Best suited $\boxed{OR}$ gate $\boxed{0-0}$ N... Cons...
- 'OR' is Used.

Aggrigate output

$y = y_1$ OR y_2 OR $y_3 \ldots\ldots$ OR y_n

$y = y_1 \cup y_2 \cup y_3 \cup \ldots\ldots \cup y_n$

$$\mu_y(y) = \max\left[\mu_{y_1}(y), \mu_{y_2}(y), \mu_{y_3}(y) \ldots \mu_{y_n}(y)\right].$$

Linguistic Variable:-

* We Studied Fuzzy logic uses linguistic variables which are the words or sentences in a natural language. Ex, If we say "Temperature", it is linguistic variable; the values of which are very hot, or cold, slightly hot or cold, very warm, or slightly warm etc.

* The words very slightly are the linguistic hedges.

Characterization of Linguistic variable

Four Terms

- Name of the variable, generally represented by X.
- Term set of the variable, generally represented by $t(x)$.
- Syntactic rules for generating the value of the variable x.
- Semantic rules for ~~Matching~~ linking every value of X and its significance.

* **Reasoning Fuzzy:-** "It mainly used in control & system analysis."

Premise 1 (fact) → X is A'

Premise 2 (rule) → if X is A then Y is B

(Conclusion) ⇒ $\boxed{\text{Y is B'}}$

(eg)= Where A' is close to A and B' is close to B.

When A', and B' are fuzzy sets of appro. Universes, the foregoing Inference procedure is called Approximate Reasoning or "**Fuzzy Reasoning**"

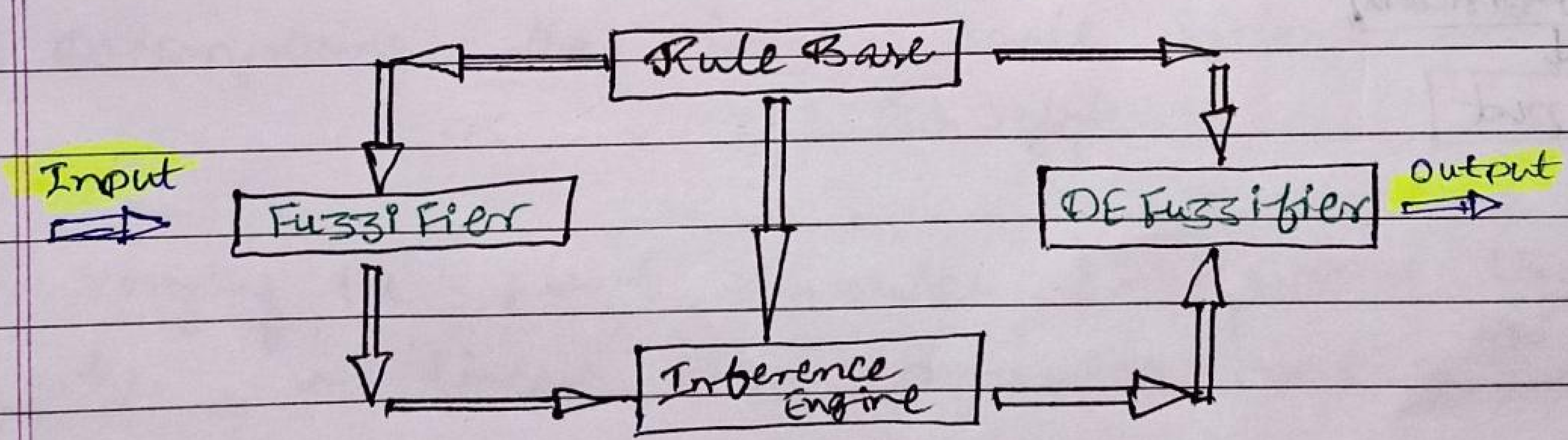
Different Modes of Reasoning:-

1. Categorical Reasoning:
2. Qualitative Reasoning:
3. Syllogistic "
4. Dispositional "

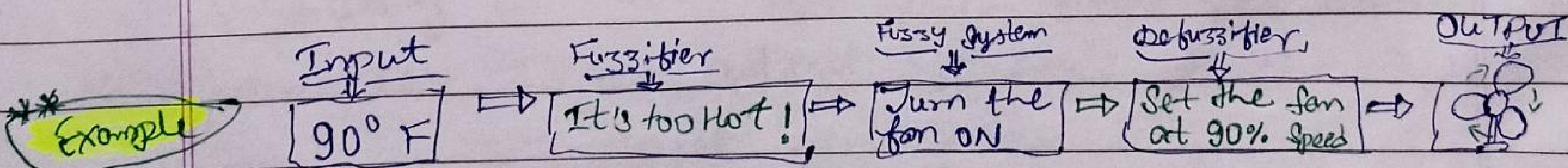
Application OF Fuzzy Logic

1. It is used in the aero space field for altitude control of spacecraft and satelite.
2. It has been used in Automative system for speed control, traffic control.
3. User for decision-making support system and personal evalution in the large company business.
4. Application in the chemistry industry for controlling the PH, drying, distillation process.
5. Electronics :- • Humidity in a clean room • Vacuum clean. • washing mashine • Microwave oven • A.C
6. Pattern Recognition & classification.
7. Medical :- • Medical diagostic support system • Multivariable control of Anesthesia • Radiology diagonoses.
8. security, Transportation (Railway, Brak & stop), Psychology.

* Architecture 'Fuzzy Logic' *



Example



* Working of Fuzzy System *

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M-5

INFERENCE ENGINE

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* It Determines the Matching degree of the current Fuzzy input with respect to each rule and decides which rules are to be fired according to the Input fields. Next, the fired rules are ~~connected~~ combined to form the ~~output~~ ~~system~~ control action.

* **Fuzzification** :- It used to convert inputs i.e. crisp Num to fuzzy set.

▷ **Three largely types of fuzzifier** :-
(1) Singleton (2) Gausian (3) Trapezoidal (or) triangular.

* **working (flow-chart Fuzzysystem)**

Input
↓
Fuzzification
↓
Inference ⟷ Control RuleBase
↓
De-fuzzification
↓
Output

M (5)

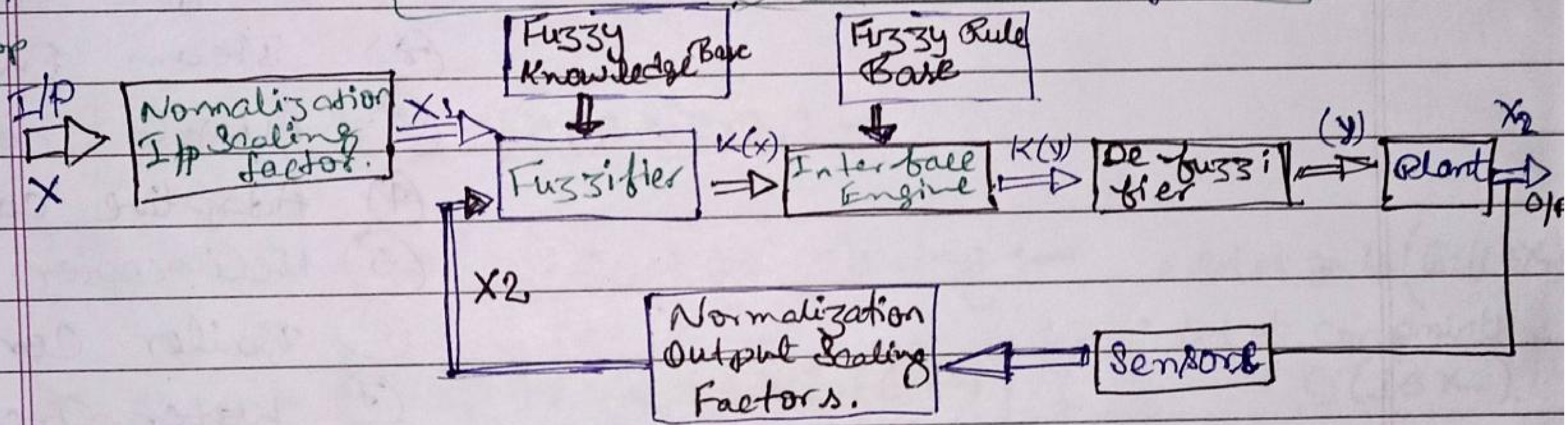
Fuzzy Control (FLC).
Controller Design

Fuzzy Logic control (FLC) is most active research area in the application of fuzzy set theory, fuzzy reasoning, and fuzzy logic.

- The application of FLC extends from industrial process control to biomedical instrumentation and securities.

Two (C.S.)
* open loop
* close loop

* Architecture OF a FLC System *



* **Control System Design:**— Designing a controller for a complex physical system involves the following steps

1. Decomposing the large-scale system into a collection of various sub systems.

2. Varying the plant dynamics slowly and linearizing the non-linear plant dynamics about a set of operation points

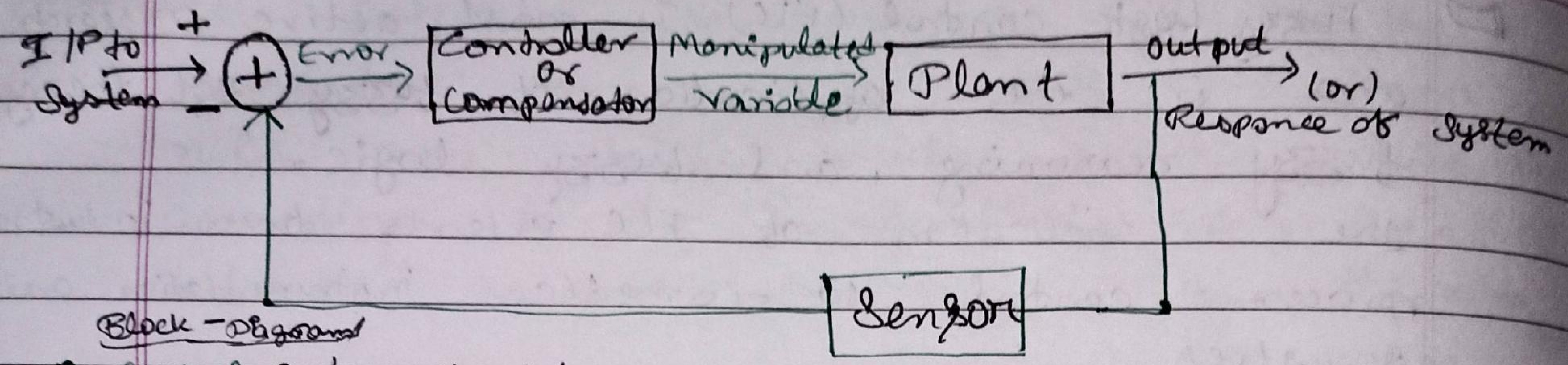
3. Organising a set of state variables, control variables, or output features for the system under consideration.

4. Designing simple, P, PD, PID controllers for the subsystems. optimal controllers can also be designed.

SC/05

FLC Fuzzy logic Controller

Control system



Block - Diagram

- Control System, closed-loop.

* Application FLC:-

1. Traffic control
2. Steam Engine
3. Missile control
4. Adaptive control
5. Heli-copter Model
6. Bailer Control.
7. Water Treatment
8. Cooling plant Contr.

~~Fu~~ Decision Making.

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* **Steps for Decision Making:-**

- **Determining the set of Alternatives:-** In this, the alternatives from which the decision has to be taken must be determined.
- **Evaluating Alternatives:-** Here, The alternatives must be evaluated so that the decision can be taken about one of the alternatives.
- **Comparison b/w Alternatives:-** A comparison b/w the evaluated alternative is done.

Types OF Decision:-

(1) Individual Decision Making:-

- set of goals $(G_i(i \in X_n))$
- Set of Constraints & $= C_j(j \in X_m)$.

$$\boxed{F_D = \min\left[i \in X_n^{in} \, f G_i(a), j \in X_m^{in} \, f C_j(a)\right]}$$

(2) Multi-person Decision Making:-

- Number of persons preferring x_i to $x_j = N(x_i, x_j)$
- Total Number of Decision makers $= n$

then, $SC(x_i, x_j) = \dfrac{N(x_i, x_j)}{m}$

(3) Multi - Objective Decision Making:-

Soft Computing

MD-5

Fuzzy

Decision Making

(4) Multi-attribute Decision Making :- It is carried out on the basis of linear equation as follows.

$$\boxed{Y = A_1 \cdot X_1 + A_2 X_2 + \dots + A_i X_i + \dots + A_n X_n}$$