Theory of Computation: [7M–10M]

1) Basics

*** 2) Regular Languages:
- Regular Expressions
- FA
- RG
- Regulars & Non-Regulars
- Closure properties
- P.L. & FA with O/P

3) DCFLs & CFLs

4) TM & Undecidability

Basics:

1) What is TOC ?

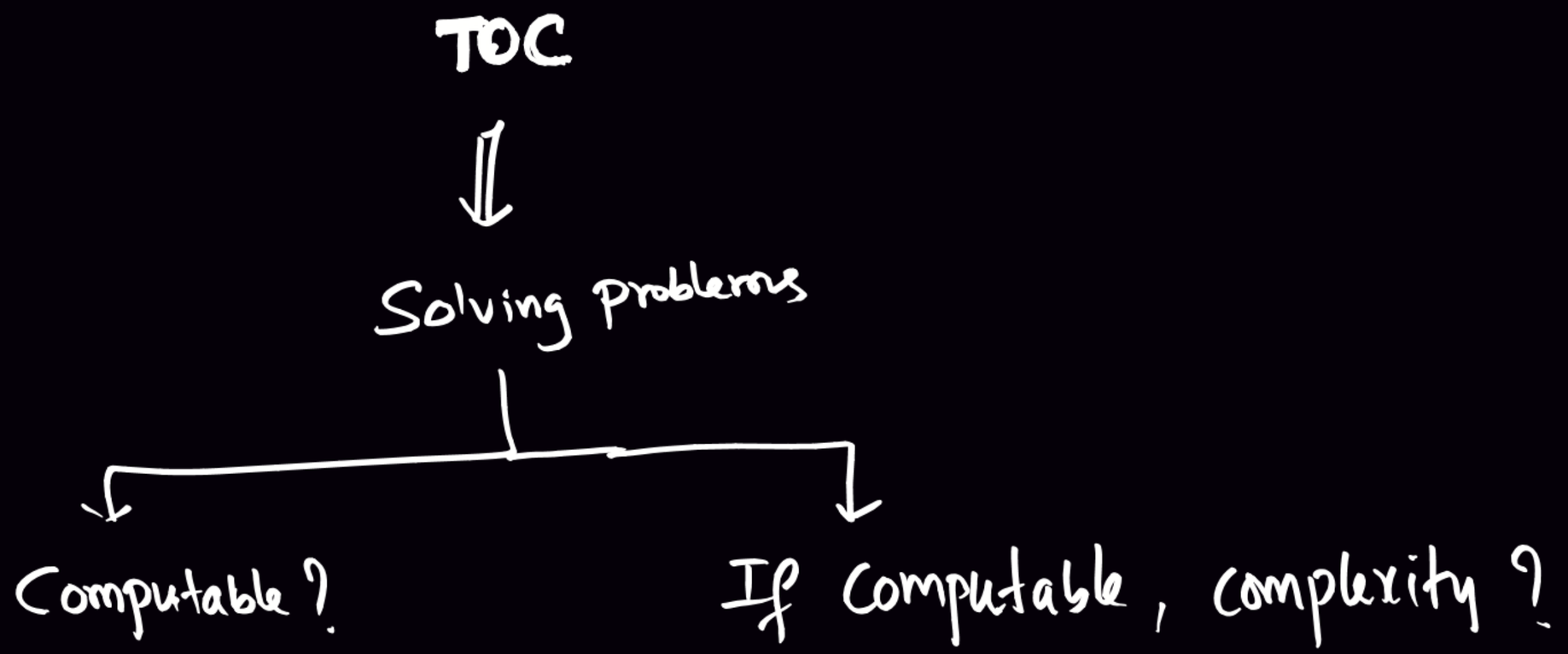
2) TOC Applications ?

3) Chomsky Hierarchy

4) Symbol, Alphabet, String, Language, Automata, Grammar

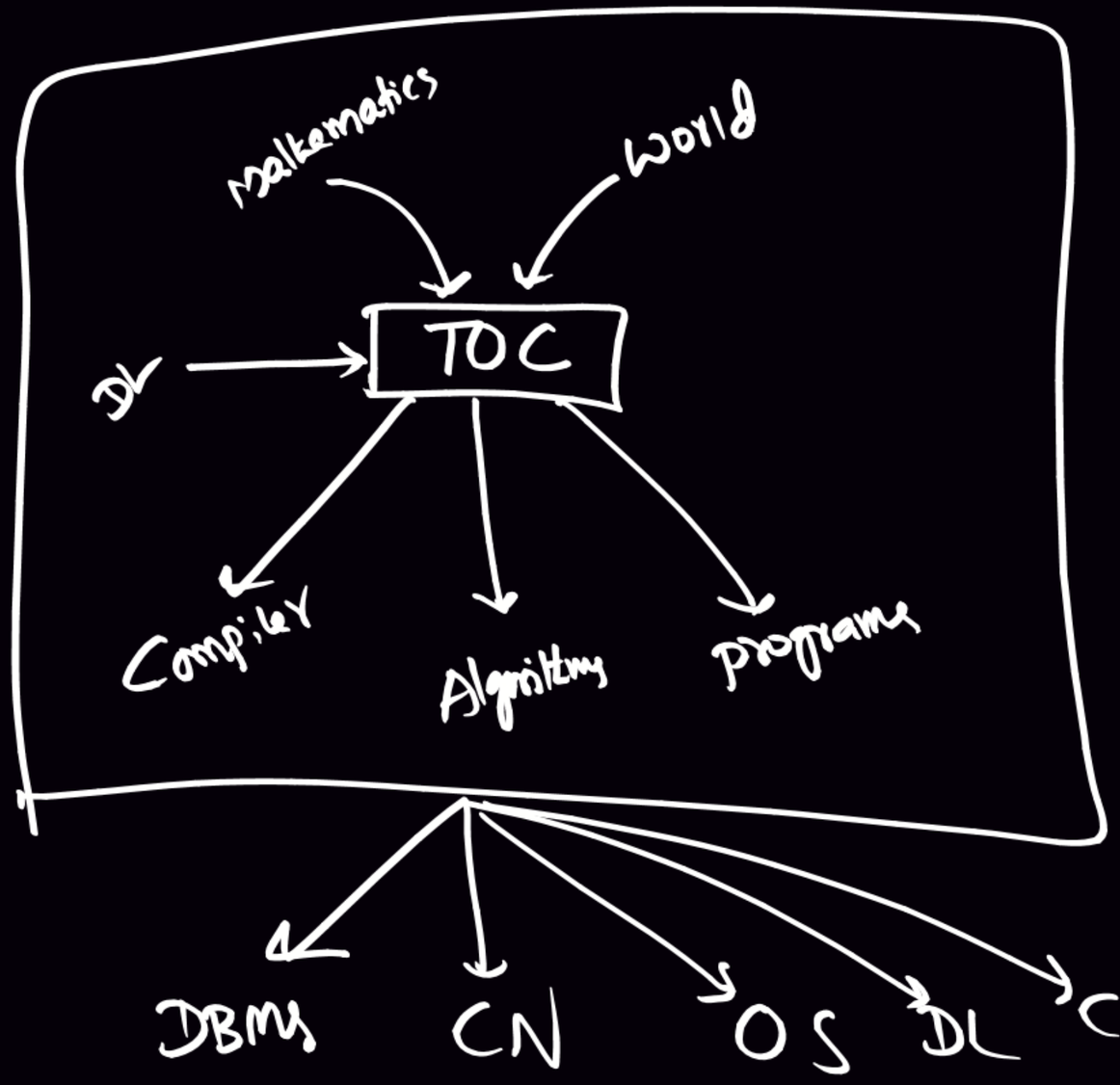
5) Operations on Strings

6) Operations on languages


TOC
Solving problems
Computable ?
If computable, complexity ?

Applications :

- Compiler Design
- Spell checker
- Traffic Signal
- Designing Digital circuit [1's comp, 2's comp, Adder, Subtractor, sequential detectors, ...]
- AI
- :

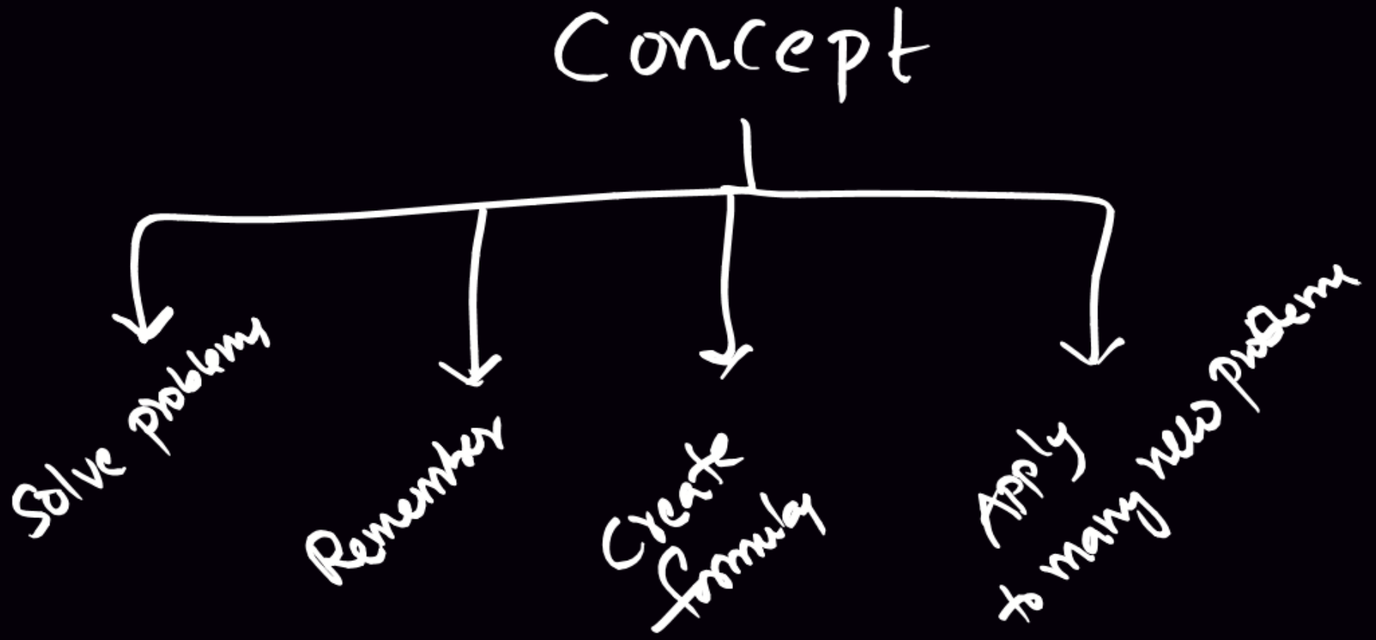


1st: Concept ?

⇓

2nd: Formula ?

90-25 Lectures



Chomsky Hierarchy :

Type-3 class = Set of all regular languages

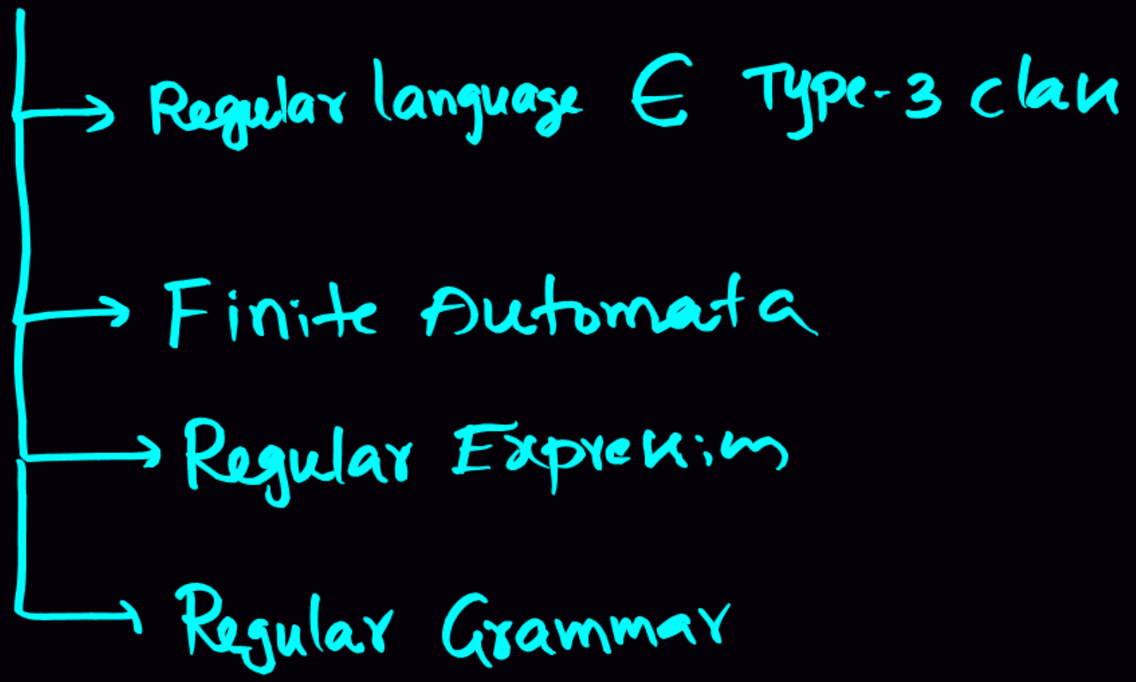
Type-2 class = Set of all CFLs

Type-1 class = Set of all CSLs

Type-0 class = Set of all Recursively Enumerable languages

Classes: $\boxed{\text{Type-3} \subset \text{Type-2} \subset \text{Type-1} \subset \text{Type-0}}$

Type-3 class :


Regular language ∈ Type-3 class
Finite Automata
Regular Expression
Regular Grammar

Class:	Type-3	Type-2	Type-1	Type-0
Language:	Regular	CFL (Context Free)	CSL (Context Sensitive)	REL (Recursively Enumerable)
Automata:	FA	PDA	LBA	TM
Grammar:	RG	CFG	CSG	UG

Basics:

TOC:

Symbol

Alphabet (Σ)(Δ)

Word/string

Language

C Language

Characters

Character set

Tokens

program → syntax, semantic, Logic?

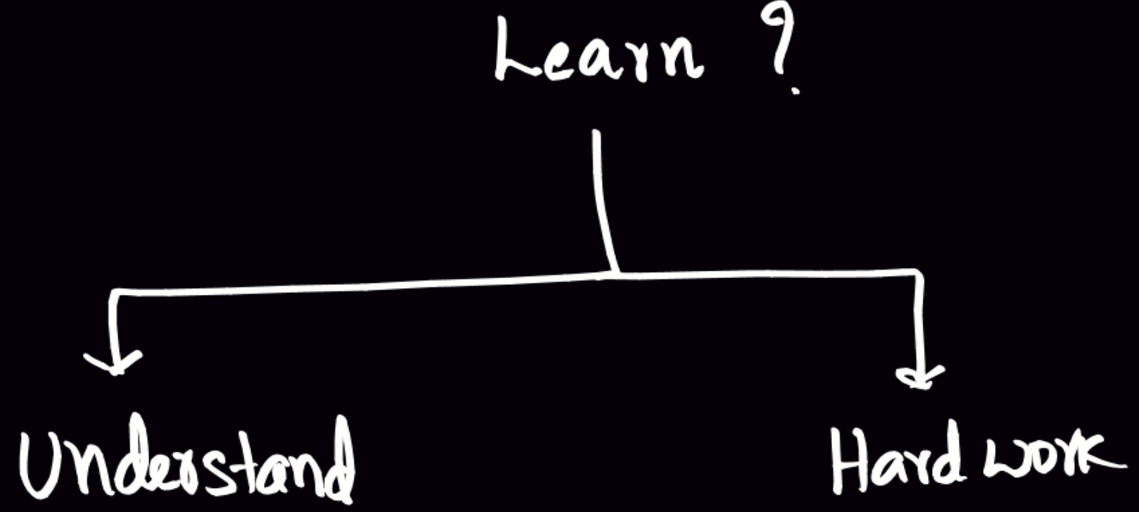
English Language:

Letter → a, b, c, ..., z (symbols)

Alphabet = {a, b, c, ..., z}
(Set)

Words: Apple
Ball
Cat
⋮

Sentence:


Learn ?
Understand
Hard work

Symbol :

- Smallest unit
- It can be any
- It should be given
- It is one

abc

Symbols: a, b, c

|abc| = 3

|a| = 1
|b| = 1
|c| = 1

Symbols: ab, c, def

|abc| = 2

|a| = no meaning
|ab| = 1
|c| = 1
|def| = 1

Symbols: abc, de, fgh

|abc| = 1

|abc| = 1

Alphabet :

- It is a set of all symbols
- It is a finite set
- It is collection of one lengths

$\Sigma = \{a, b\}$

$|a| = 1$

$|b| = 1$

$\Sigma = \{gate, exam\}$

$|gate| = 1$

$|exam| = 1$

$\Sigma = \{a, b, c, \cdots, z\}$

$|gate| = 4$

$|rank| = 4$

$|topper| = 6$

$$\Sigma = \{ (0,0), (0,1), (1,0), (1,1) \}$$

$$|(0,0)(1,0)(1,1)(0,0)(0,1)| = 5$$

$\Sigma = \{$  $\}$

$|$  $| = 3$

$\Sigma = \{ abc, 01, +- \}$

$|abcabc01+-01| = 5$

String [word]:

→ It is a sequence of symbols

→ It is a finite sequence

$\Sigma = \{a, b\}$

Zero length : ε

one sequence (one length): a, b

Two length : aa, ab, ba, bb

3 length Strings : aaa, aab, aba, abb, baa, bab, bba, bbb

$2 \times 2 \times 2 = 2^3 = 8$ strings

$\Sigma = \{a, b, c, d\}$

How many 7 length strings?

4 choices

$4 \times 4 \times 4 \times \ldots$ 7 times $= 4^7$

How many k-length strings over $\Sigma = \{a, b\}$?

2 choices, 2 choices

$2 \times 2 \times 2 \times \ldots$ k times $= 2^k$ strings

Zero length string (Empty string)(Null strings)

- It is special string with zero no. of symbols.
- Denotated using ε or λ

$\Sigma = \{a, b\}$

$|\varepsilon| = |\ | = 0$

a is symbol

b is symbol

Is ε symbol ?

- NO
- It is empty string

$\Sigma = \{a\}$ ⇒ Strings upto 3 length ? (≤ 3)

ε

a

aa

aaa

$\Sigma = \{0, 1, 2\}$ ⇒ write strings upto 2 length.

ε	3^0
0	
1	3^1
2	
00	
01	
02	
10	
11	3^2
12	
20	
21	
22	

2 length

3 choices × 3 choices

How many strings upto 2 length ?

$= 3^0 + 3^1 + 3^2$

$= a^0 + a^1 + a^2 + \dots + a^n$

$= \frac{a^{n+1} - 1}{a - 1}$

$= \frac{3^3 - 1}{3 - 1} = \frac{26}{2} = 13$

Language [Set] [collection]

↳ Set of strings over Σ.

$\Sigma = \{a, b\}$

$L_1 = \{\} = \phi$ = Empty Language

$L_2 = \{\varepsilon\}$

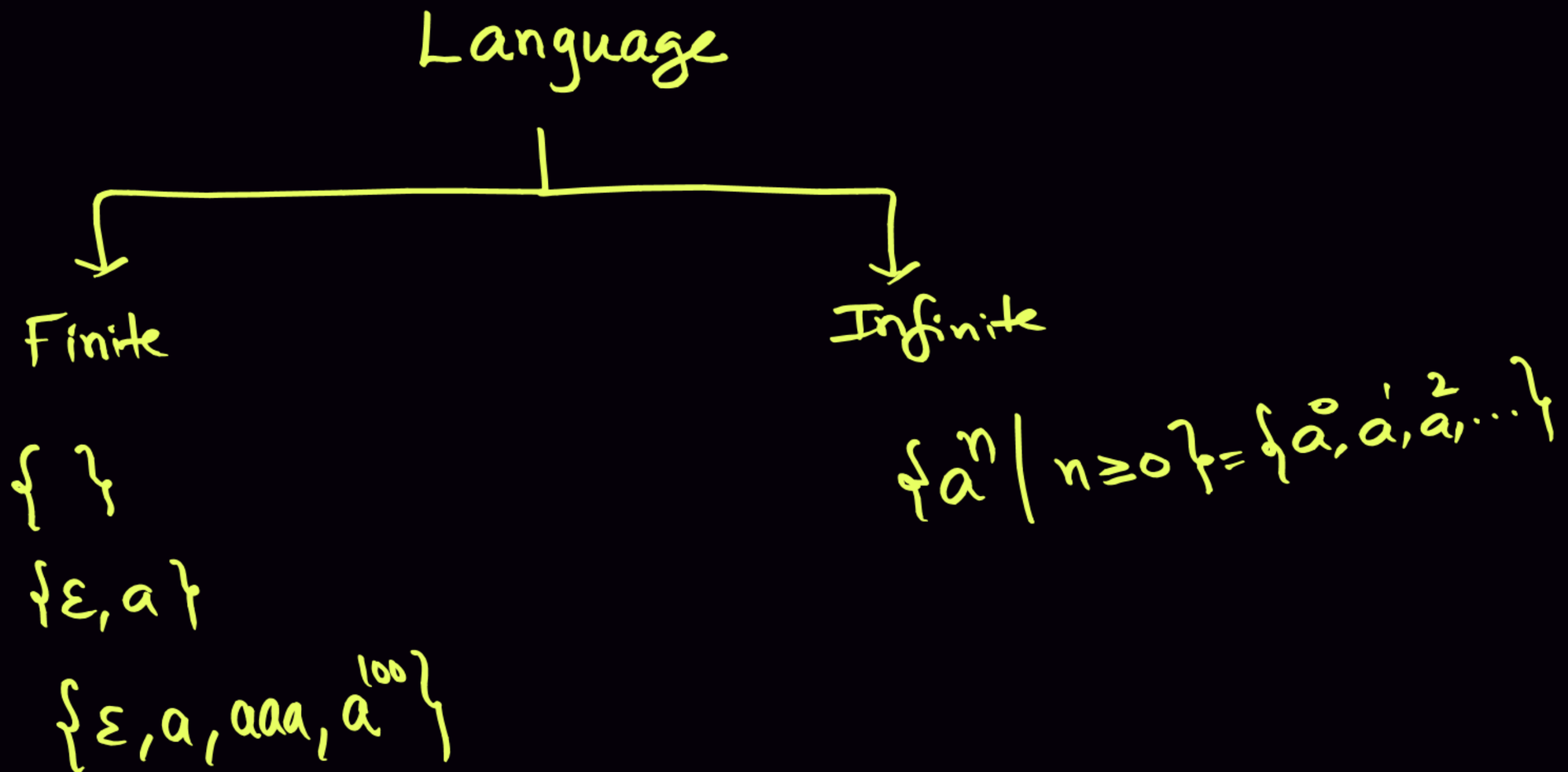
$L_3 = \{\varepsilon, a, abb\}$

ε string

ϕ lang

$|\varepsilon| = 0$

$|\{\varepsilon\}| = 1$


Language
Finite
Infinite
{ }
{ε, a}
{ε, a, aaa, a^100}
{a^n | n≥0} = {a^0, a^1, a^2, ...}

ε → empty string

$\{\} = \phi$ → empty set

$\{\varepsilon\}$ → non empty set which has one string.

$|\varepsilon| = 0$

$|\text{string}|$

Length of string

$|\phi| = |\{\}| = 0$

$|\text{set}|$

Size of set

no. of objects in set

$|\{\varepsilon\}| = 1$

Automata

↳ m/c

Grammar

↳ collection of rules

I want to find even.

Problem

In real world

In TOC

Even Language

$\{\varepsilon, aa, a^4, a^6, \ldots\}$

Language

If Computable, we will show model (automata/grammar/...)

H.W.:

I) Let $w = aaaa$.

1) No. of prefixes of w =
2) " Suffixes " =
3) " Substrings " =

II) Let $w = abcd$

1) No. of prexies =
2) No. of Suffixes =
3) No. of Substring =

$|string|$

Length of string

$|\underrightarrow{abc}| = 3$

$|Set|$

Size of set

$|\{1, 5, 37, 8\}| = 4$

Symbol ⟶ any

Alphabet ⟶ collection of all symbols

String ⟶ Sequence of symbols

Language ⟶ collection of strings