Compiler Design

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Compiler :- Executes whole code in one time
↳ C, C++, ... → Languages for software development

Interpetor :- Line by line execution
↳ Small Code use → Web based Language

→ Compiler execute whole program at a time.
↳ Large Code Use
ex. C, C++, Java, Pascal, COBOL, BASIC
↳ Programming Language

* **Intrepretor example** :- Ruby, Python, ASP.NET, Perl
↓
Scripting language

COBOL → Common Business oriented Language

BASIC → Beginner All Purpose symbolic Instruction Code.

* **Markup Language** → HTML, XML → No use they just help ~~in Enterprise~~ with scripting language

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* **Grammar** :- 4 Tuple

(V, T, P, S)

- V → Non Terminal
- T → Terminal
- P → Productional rule
- S → Starting Symbol

(1) **Terminal** :- Small Letter
(a-z) (0-9)

(2) **Non Terminal** :-
(A-Z)

(3) **Production Rule** :- $S \rightarrow abc$ (P.R.)

(4) **Starting Symbol** :- $S \rightarrow abc$
S (S.S.)

Regular Grammar (R.G.) → Finite length.
Least Powerful
↳ 4 Tuple (V, T, P, S)
↳ Two form → Left linear Regular Grammar **
Right linear Regular Grammar **

(1) **Left linear Regula Grammar** :-
Non Terminal on left

$S \rightarrow Aaa$
$S \rightarrow Bba$
$S \rightarrow Xaaa$

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(2) **Right Linear Regular Grammar :-**

$S \longrightarrow aa\,A\,\boxed{A}$
$S \longrightarrow aB\,a\,\boxed{B}$
$S \longrightarrow aX\,aa\,X\,\boxed{B}$

★ $S \longrightarrow \boxed{A}aa\boxed{A}$
$S \longrightarrow \boxed{B}\boxed{B}$
$S \longrightarrow \boxed{Z}X\,A\,\boxed{B}$
$S \longrightarrow \boxed{A}aa\,X\,a\,\boxed{B}$
→ Left, Right both

Q. N.T.
$S \longrightarrow aa$ ✗
$S \longrightarrow \epsilon$ ✗
$S \longrightarrow aaaa$ ✗
→ R.G. ✗

* If it is R.G. then it will be C.F.G., C.S.G., Unrestricted Grammar

Q. (i) $S \longrightarrow aA\boxed{A}$
$S \longrightarrow aab$
$A \longrightarrow a$
→ Right linear grammar
R.G. ✓

(ii) $S \longrightarrow aaAa$
$S \longrightarrow \boxed{A}\boxed{A}$
$S \longrightarrow B$
$S \longrightarrow a$
$B \longrightarrow b$
Both linear grammar
Regular Grammar

(iii) $S \longrightarrow aAa$
$S \longrightarrow aBa$
R.G. ×

Q. (i) $A \longrightarrow aaAaA$
$B \longrightarrow bb$
R.G. ✓ (Right Linear)

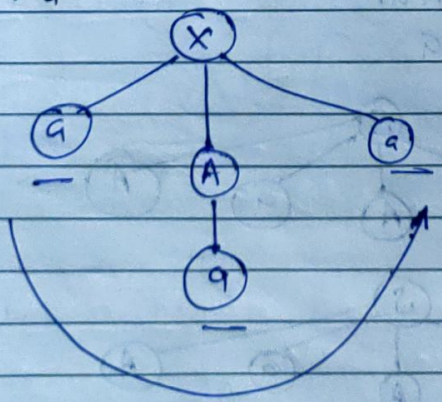
(ii) $B \longrightarrow b$
$A \longrightarrow aAa$
$A \longrightarrow aa$
R.G. ×

(iii) $A \longrightarrow aAA$
$B \longrightarrow BB\epsilon$ (ε → Empty)
Both Linear
R.G. ✓

(1) Derivation Tree :-

Starting Node → Root Node
Vertex → Non Terminal
Leaf Node (leaves) → Terminal

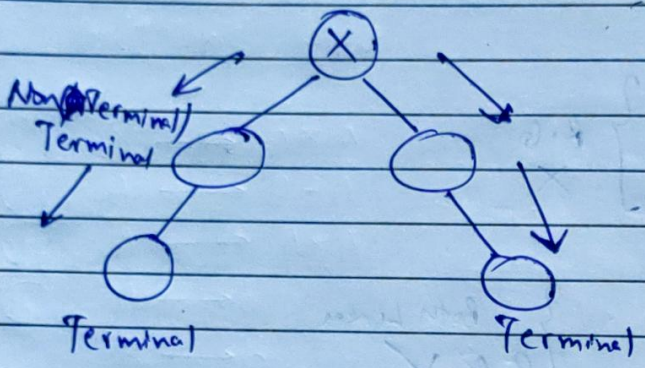
$X \longrightarrow aAa$
$A \longrightarrow a$



⇒ aaa

(i) Top-down derivation tree -

(i) Start with Root Node.
(ii) Goes down TOward leaf Node (leaves)



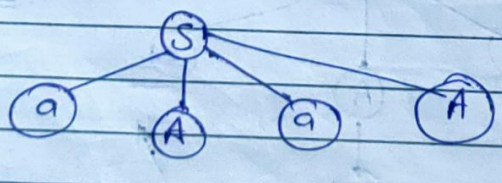
(ii) Bottom-up derivation tree :-

(i) Start with leaf Node (leaves Node)
(ii) Towards Root Node.

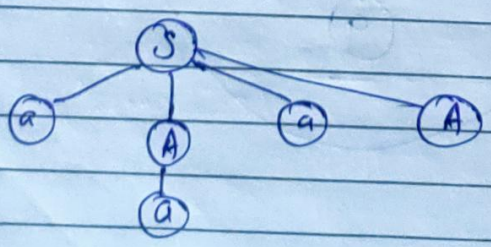
(i) left linear derivation tree :-

Root Node ← S → aAaA
A → a

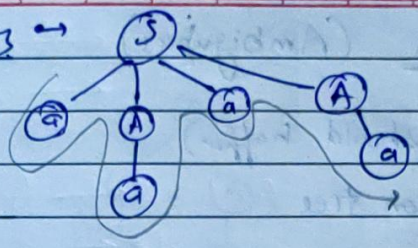
Step 1 →



Step 2 →



Step 3 →



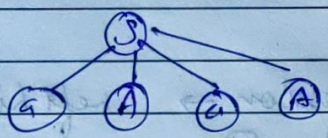
S → aaaa

(ii) Right linear derivation tree :- (Right to left)

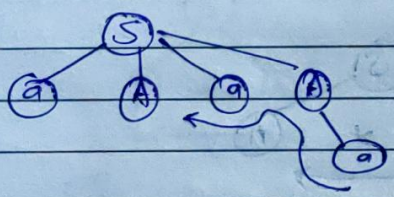
S → aA aA

~~A~~ → a

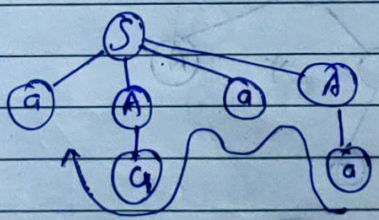
Step 1 :-



Step 2 :-



Step 3 :-



S → aaaa

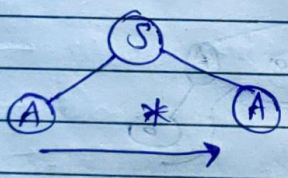
Ambiguity Grammar (Ambiguous)

(Any one should happen)

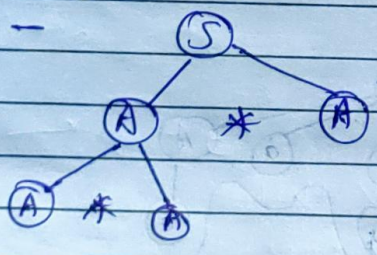
(i) Left linear derivation tree
(ii) Right " " "
(iii) Left and Right " "

Q. (i) $S \longrightarrow A * A$
(ii) $A \longrightarrow A + A$
(iii) $A \longrightarrow A * A$
(iv) $A \longrightarrow a$
(v) $B \longrightarrow b$

Take any expression → left linear →
we take (i)

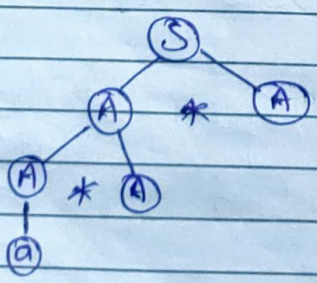


Step 1 –



we use (iii) now

Step 2 :-



we use (iv) now

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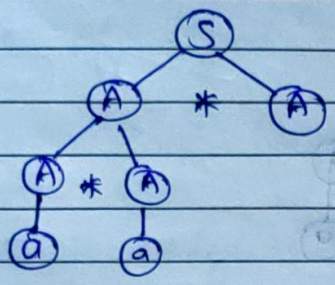
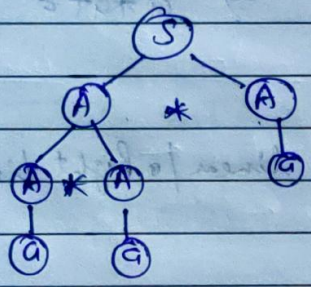
Step 3 :-

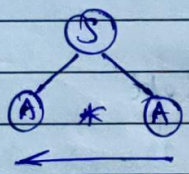


Step 2 :-

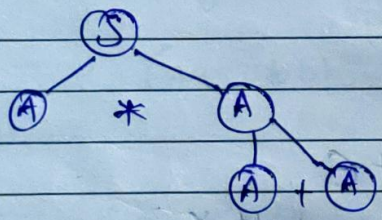


⇒ a * a * a

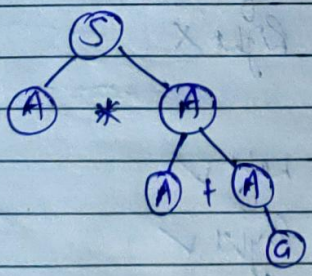
Right Linear :-



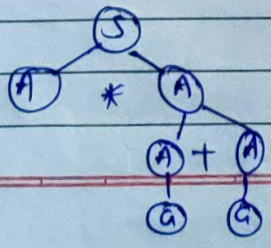
Step 1 :-



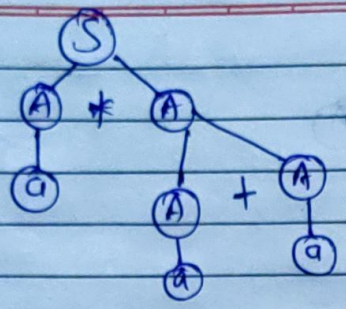
Step 2 :-



Step 3 :-



Step 4:-



⇒ a*a+a

Q. Find out left linear / Right linear Regular Gram.

(1)
$S \rightarrow aaAB$
$S \rightarrow aAB$ Right
$A \rightarrow a$
$B \rightarrow b$

(2)
$S \rightarrow Aaa$ Left
$S \rightarrow Bb$
$A \rightarrow a$
$B \rightarrow b$

(3)
$S \rightarrow \epsilon + \epsilon$

Left ✗
Right ✗

(4)
$S \rightarrow AaaA$
$S \rightarrow BA$
$A \rightarrow a$
$B \rightarrow b$

Left ✓
Right ✓

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Power of Sigma :-

$\Sigma = (a, b)$

(i) Σ^0 ⟶ only Empty string
Σ^0 ⟶ Empty

(ii) Σ^1 ⟶ Set of all string of length 1
Σ^1 ⟶ (a, b)

(iii) Σ^2 ⟶ Set of all string of length 2
Σ^2 ⟶ (aa, ab, ba, bb)

(iv) Σ^3 ⟶ Set of all string of length 3
Σ^3 ⟶ (aaa, bbb, abb, baa, bab, aba, aab, bba)

(v) Σ^4 ⟶ Set of all string of length 4
Σ^4 ⟶ (aaaa, ...)

(vi) Σ^n ⟶ Set of all string of length n

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① Kleene Closure (*)

$\Sigma = (a, b)$

$\Sigma^* = (\text{Empty}, a, b, aa, ba, \ldots)$

② Kleene Plus (+)

$\Sigma = (a, b)$

$\boxed{\Sigma^+ = \Sigma^* - (\text{Empty})}$

$\Sigma^+ = (a, b, aa, bb, \ldots)$

Regular Language :- ('L')

↳ Language accepted by Regular grammar is called Regular Language.

$\Sigma = (a, b)$

$a^* = (\text{Empty}, a, aa, aaa, \ldots)$

$a^+ = (a, aa, aaa, \ldots)$

$\Sigma = (a, b)$

$L^1 = (a, b)$
$L^2 = (aa, bb, ab, ba)$
$L^3 = (aaa, aab, abb, bbb, \ldots)$
$L^4 = (aaaa, aaab, aabb, abbb, \ldots)$

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$\Sigma = (a, b, c, d)$

$L^1 = (a, b, c, d)$
$L^2 = (ab, ac, ad, ba, bd, \ldots)$
$L^3 = (abc, bcd, \ldots)$

* Five Properties of Regular Language :-

(1) Union — if we have 2 Regular language L_1 and L_2. Then Union of $L_1 \cup L_2$ are Regular Language.

Ex. $L_1 = (a, b)$
$L_2 = (a, c)$
$L_1 \cup L_2 = (a, b, c)$

(2) Complement — if we have 2 Regular language L_1 and L_2. Then complement of L_1' and L_2' are Regular Language.

$L_1 = (a, b)$ $\quad L_1' = (b, a)$
$L_2 = (a, c)$ $\quad L_2' = (c, a)$

(3) Concatenation :- if we have 2 regular language L_1 and L_2. Then concatenation of $L_1 \cdot L_2$ are regular language.

$L_1 = (a, b)$
$L_2 = (a, c)$

$L_1 \cdot L_2 = (aa, ac, ba, bc)$

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(4) **Kleene Closure (*)**:- if we have 2 Regular language L_1 and L_2. Then Kleene closure of L_1^* and L_2^* are Regular Language.

$L_1 = (a, b)$
$L_2 = (a, c)$

$L_1^* = (Empty, a, b, aa, bb, ab, ba, \ldots.)$
$L_2^* = (Empty, a, c, aa, ac, cc, ca, \ldots)$

(5) **Intersection ($\cap$)**:- if we have 2 Regular language L_1 and L_2. Then intersection of $L_1 \cap L_2$ are regular language.

$L_1 = (a, b)$
$L_2 = (a, c)$

$$L_1 \cap L_2 = (a)$$

★ **Precedence** ⟶

(1) Kleene Closure (*) Highest Priority

(2) ~~Second~~ Concatenation

(3) Union (lowest)

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Normal Form

CNF (Chomsky Normal Form)

GNF (Greibach Normal form)

1) CNF :-

Conditions -

(i) Non-Terminal Represent to empty symbol.

$A \longrightarrow \epsilon$

(ii) Non-Terminal Represent to Terminal.

$A \longrightarrow b$, $A \longrightarrow c$

(iii) Non-Terminal represent atleast to 2 Non Terminal
$(V \rightarrow V_1 V_2)$

$A \rightarrow BC$, $A \rightarrow AB$, $A \rightarrow BD$

2) GNF :-

Conditions -

(i) Non-Terminal Represent to empty symbol.

$A \longrightarrow \epsilon$

(ii) Non-Terminal Represent to Terminal

$A \rightarrow b$, $A \longrightarrow c$

(iii) Non-Terminal Represent Terminal followed by Non Terminals. $(a\alpha^*)$

$A \to aB$, $A \to aBC$, $A \to aBCD$, $A \to aABCD$

↓

Only one termind followed by terminals

Q.(i)

$A \to d$ ✓

$A \to \epsilon$ ✓ CNF ✗

$A \to Aa$ ✗ GNF ✗

$A \to a$ ✓ Regular Grammer ✓ (VTPS)

(ii)

$A \to a$ ✓

$A \to \epsilon$ ✓ CNF ✓

$A \to BC$ ✓ GNF ✗

(iii)

$A \to a$ ✓

$A \to b$ ✓ CNF ✗

$A \to aaA$ ✗ GNF ✗

$A \to b$ ✓

(iv)

$A \to a$ ✓

$A \to \epsilon$ ✓ CNF ✗

$A \to aBCDEFGHIJ$ ✓ GNF ✓

(v)

$A \to a$ ✓

$A \to \epsilon$ ✓ CNF ✓

$A \to BC$ ✓ GNF ✗

(vi) $A \to \epsilon$ ✓
$A \to b$ ✓
$A \to aBC$ ✓

CNF ✗
G.N.F. ✓

CFL (Context free Language) :-

Properties :-

(i) Union : if we have 2 Context free language L_1 and L_2 then union of ~~Context free~~ $L_1 \cup L_2$ are CFL.

(ii) Complement :- if we have 2 Context free language L_1 and L_2 then complement of L_1' and L_2' are ~~CFL~~ NOT CFL.

(iii) Concatenation :- if we have 2 CFLs L_1 and L_2. then concatenation of $L_1 \cdot L_2$ are CFL.

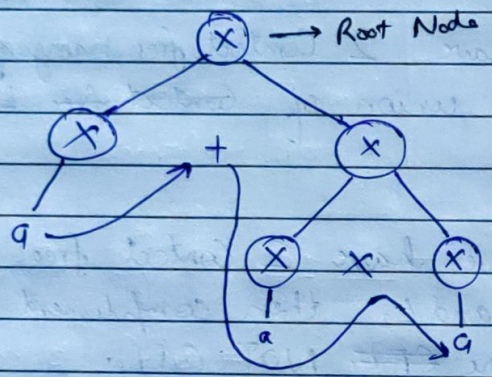
(iv) Kleene Closure (*) :- if we have 2 CFLs L_1 and L_2. then Kleene Closure L_1^* and L_2^* are CFL.

(v) Intersection :- if we have 2 CFLs L_1 and L_2 then intersection of $L_1 \cap L_2$ are NOT CFL.

(Parse Tree)

Q. Find out left Most Derivation tree
Final string "a+a*a"

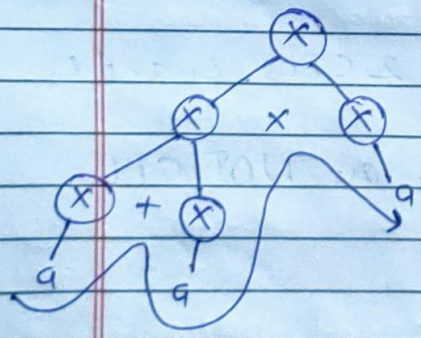
$X \rightarrow X+X$ — (1)
$X \rightarrow X$
$X \rightarrow X*X$ — (3)
$X \rightarrow a$



a+a*a

Q. Right ~~Left~~ Most Derivation tree → (Parse tree)

$X \rightarrow X+X$ — (3)
$X \rightarrow X$
$X \rightarrow X*X$ (1)
$X \rightarrow a$



a+a*a

* If more than one parse tree are possible, like in this example left & Right derivation tree are

different, therefore this is Ambiguous Grammar.

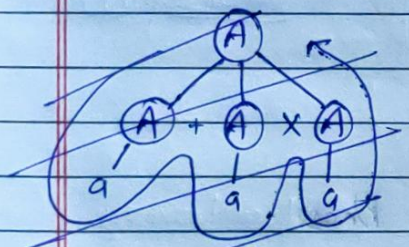
* If the structure of left and Right derivation tree are same then grammar is Unambiguous grammar.

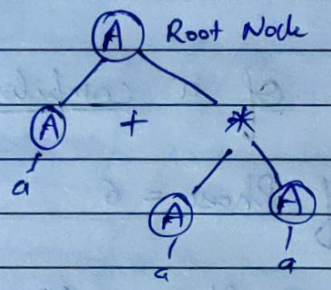
Q. Find out left most derivation tree and right.

$A \longrightarrow A+A*XA$
$A \longrightarrow AXA+A$
$A \longrightarrow a$

$\Rightarrow A \longrightarrow A+(AXA)$

Left most →





a+axa
Sahi tha yeh bhi

diff. structure & diff. strings → Ambiguous

* For Unambiguous –
(i) ek se jyada left ban jaayen
(ii) " " " right " "
(iii) ek se jyada dono ban jaayen

Ambiguous	Unambiguous
(i) More then one left and right derivation tree.	(i) Only one left and one right derivation tree.
(ii) Different structure of Derivation tree.	(ii) Same structure of derivation tree.
(iii) (1) More than one left derivation tree. (2) More than one right derivation tree. (3) More than one left and right derivation tree.	

Phases of a compiler -

* No. of Phase = 6
* First 3 Phase called Analysis Phase.
* Last 3 Phase called Synthesis Phase.

Analysis Phase -

(i) Lexical Phase

(ii) Syntax Phase

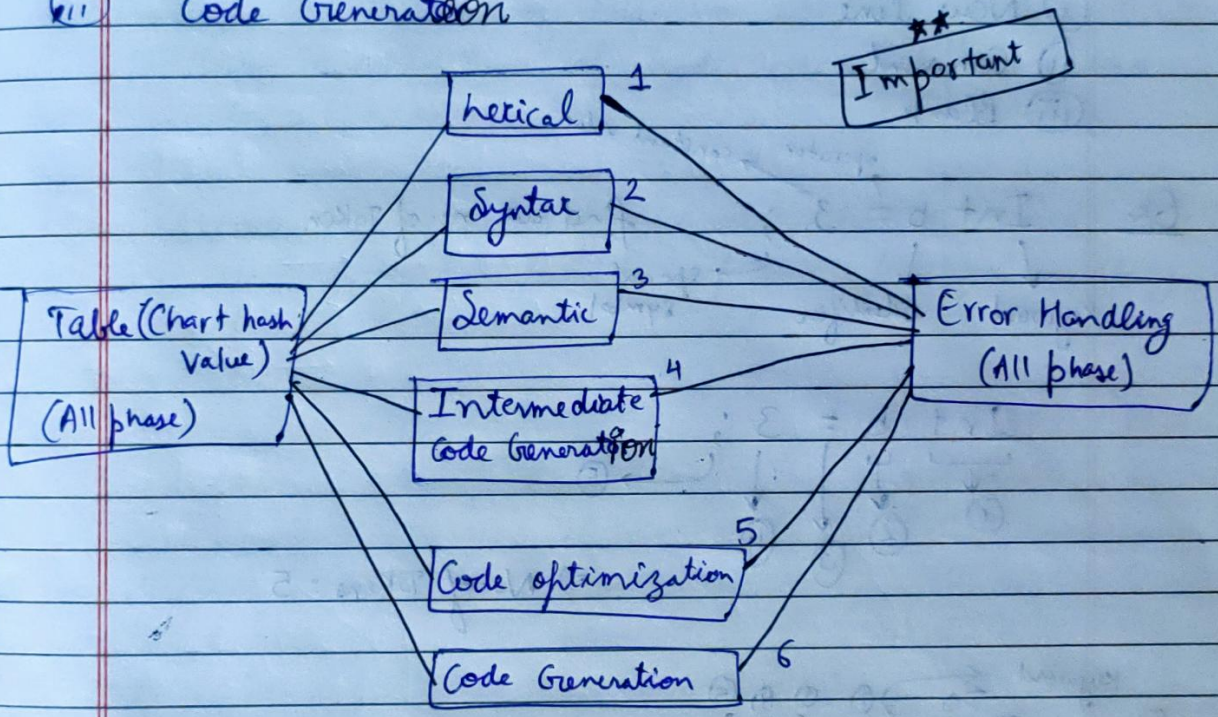
(iii) Semantic Phase

Synthesis Phase -

(i) Intermediate Code Generation

(ii) Code optimization

(iii) Code Generation



☆ Token :- Sequence of character which represent unit of Information in the code.

(i) Identifier :- (a, b)

(ii) Keyword → INT, VOID

(iii) Constant value → 5, 6, 0, 1

(iv) Special Symbol → , ;

(v) Operator → Bitwise, Arithmetic

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☆ Non-Token :-

(i) New line
(ii) Comment
(iii) Blank

Ex. `Int b = 3 ;` — find out no. of Token

operator, constant value, special symbol

Int → Keyword; b → Identifier; = → operator; 3 → constant value; ; → special symbol

Int b = 3 ;
① ② ③ ④ ⑤

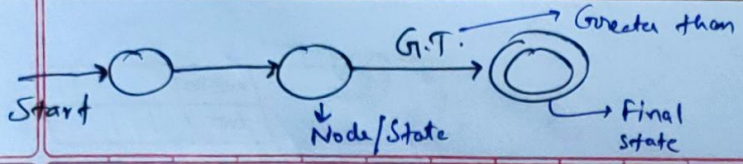
⇒ No. of Tokens = 5

Ex.
```
Int main ( ) {
Printf ( " My Name is ------- " ) ;
return 0 ;
}
```

Keyword: Int

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭

⇒ ⑭ Ans.



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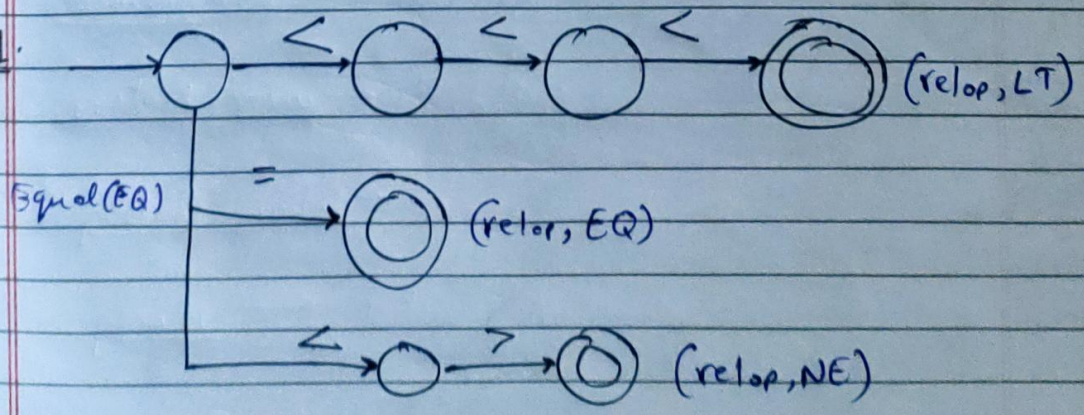
Transition Diagram :-

(1) **States** - Transition Diagram which represent collection of nodes or circle is called states.

(2) **Lexeme** - Sequence of character in the source program which represent pattern matching for a Token.

Lexeme	Token Name	Attribute
if	if	—
Then	Then	—
else	else	—
Any Identifier	Id	—
Any Number	Number (Num)	—
<	relop	LT
>	relop	GT
=	relop	EQ
<=	relop	LE
>=	relop	GE
** <>	relop	NE (Not Equal)**

Ex. 1.



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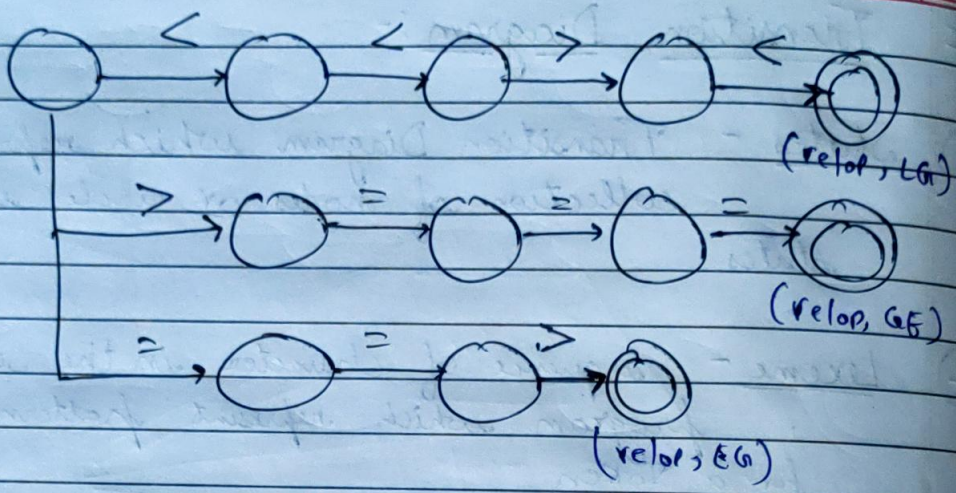
Ex. 2.



① (LT GT)
↓ ↓
~~(LG)~~ (NE)

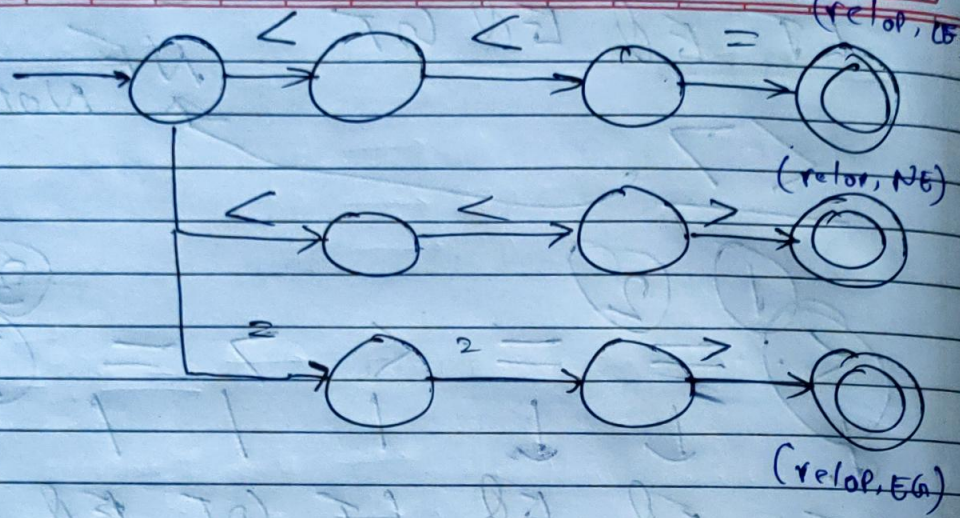
② (GT, EQ)
↓ ↓
(GE)

③ (EQ, GT)

(EQ)

=>

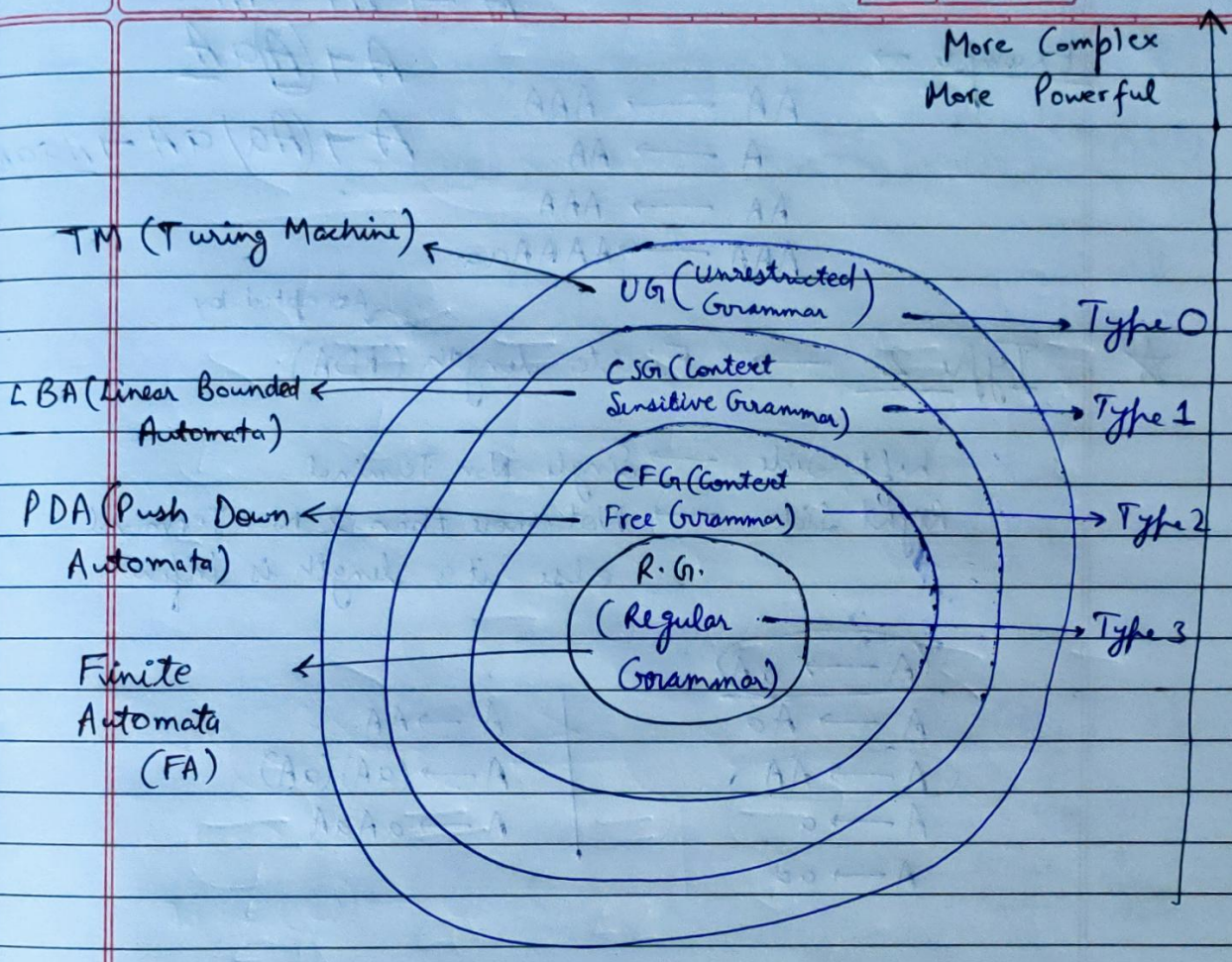
Ex.3.



① (LT, EQ)
(LE)

② (LT, GT) < >
~~(LG)~~ ↓ NE

③ (EQ, GT)
(EG)



★ Type 0 → Infinite length (TM)

Example →

$A \longrightarrow AAAA$
$AA \longrightarrow A$
$AAA \longrightarrow A$
$AA \longrightarrow AA$

$AAA \longrightarrow A$
$AAa \longrightarrow AaA$
$aA \longrightarrow a$

★ Type 1 → Infinite length (LBA)

left < Right

$A \to AA$

$A \to A(aA)$ | $A \to (A)aA$

$A \to (Aa)/aA \to Aaa$

Example →

$AA \longrightarrow AAA$

$A \longrightarrow AA$

$AA \longrightarrow AAA$

$AAA \longrightarrow AAAAaa$

★ Type 2 → Finite length (PDA) — Accepted by

Left Side → Single Non Terminal

Right Side → Not more than 2 Non Terminal else it's length is infinite

$A \longrightarrow aA$

$A \longrightarrow Aa$

$A \longrightarrow AA$

$A \longrightarrow a$

$A \longrightarrow aa$

$A \to AA$

$A \to (aA)(aA)$

$A \to aAaA$

★ Type 3 → Finite length (FA)

$A \to a$

$A \to aA$

$A \to Aa$

$A \to aa$

Type	Grammar	Language	Automata
Type 3	RG	Regular Language	FA
Type 2	CFG	CFL	PDA
Type 1	CSG	CSL	LBA
Type 0	UG	Recursive Language	TM

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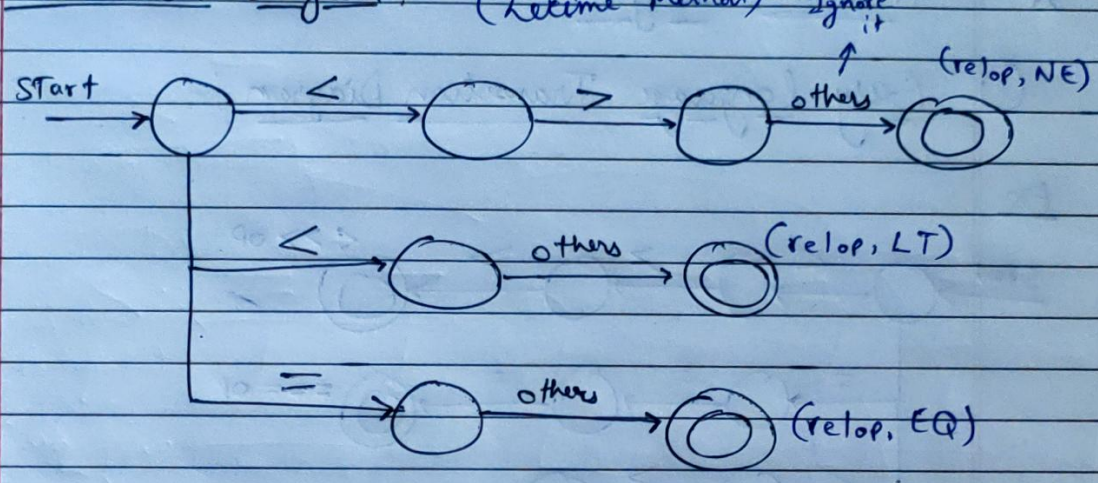
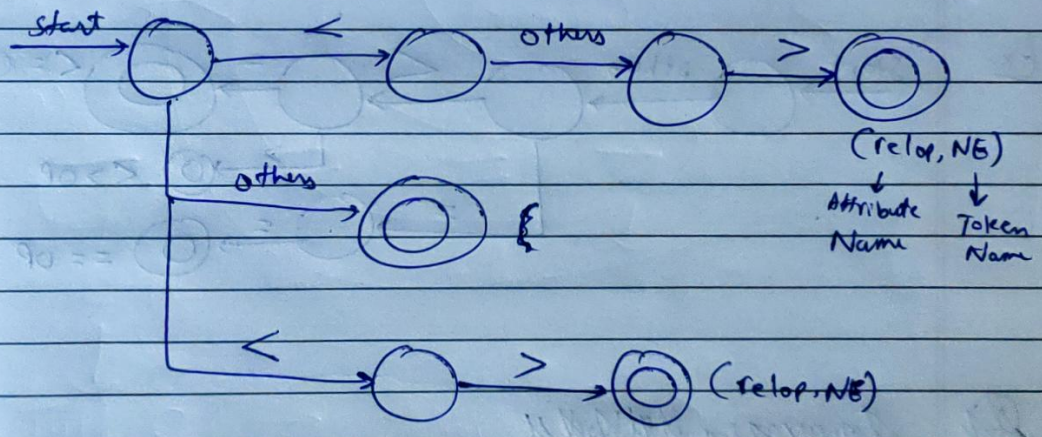
Transition Diagram :- (Lexime Method)

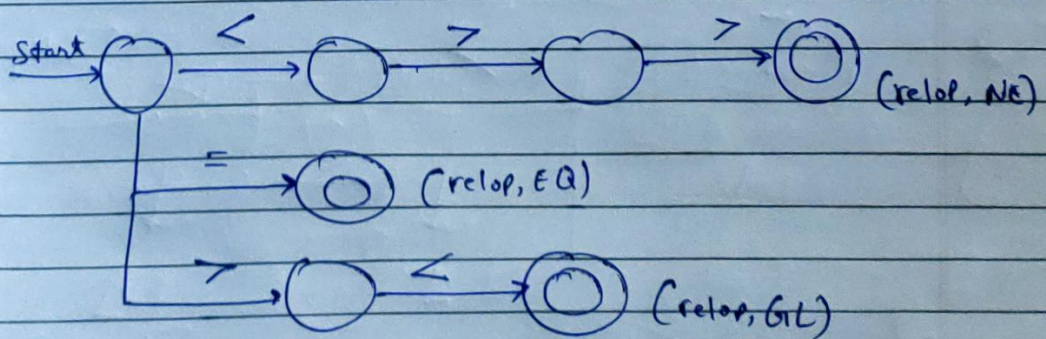
Ex 1.



Ex 2.



Ex 3.



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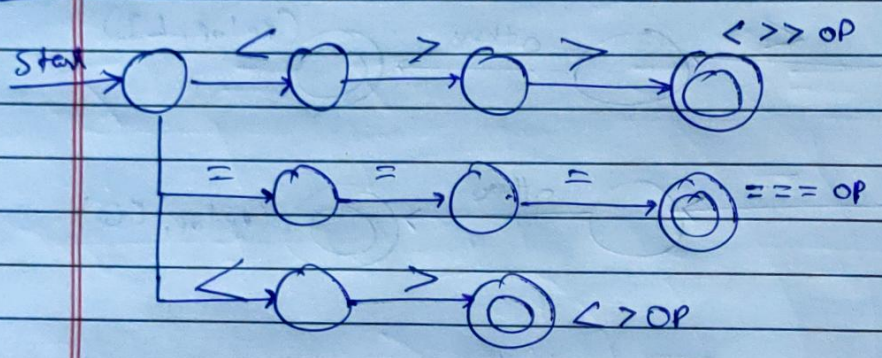
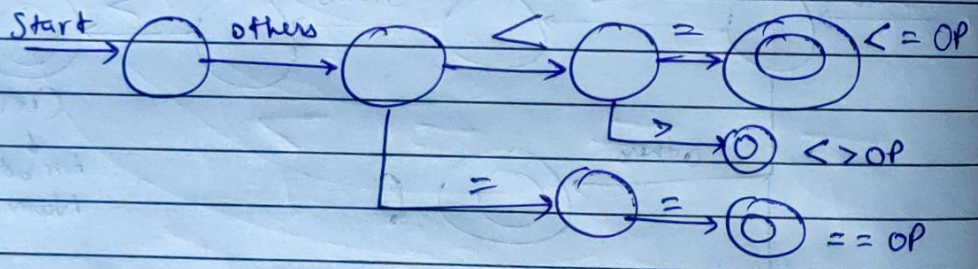
★ Transition Diagram :-

① Easy Language Transition Diagram :-

Ex.



Ex.



② ~~Language Method :-~~