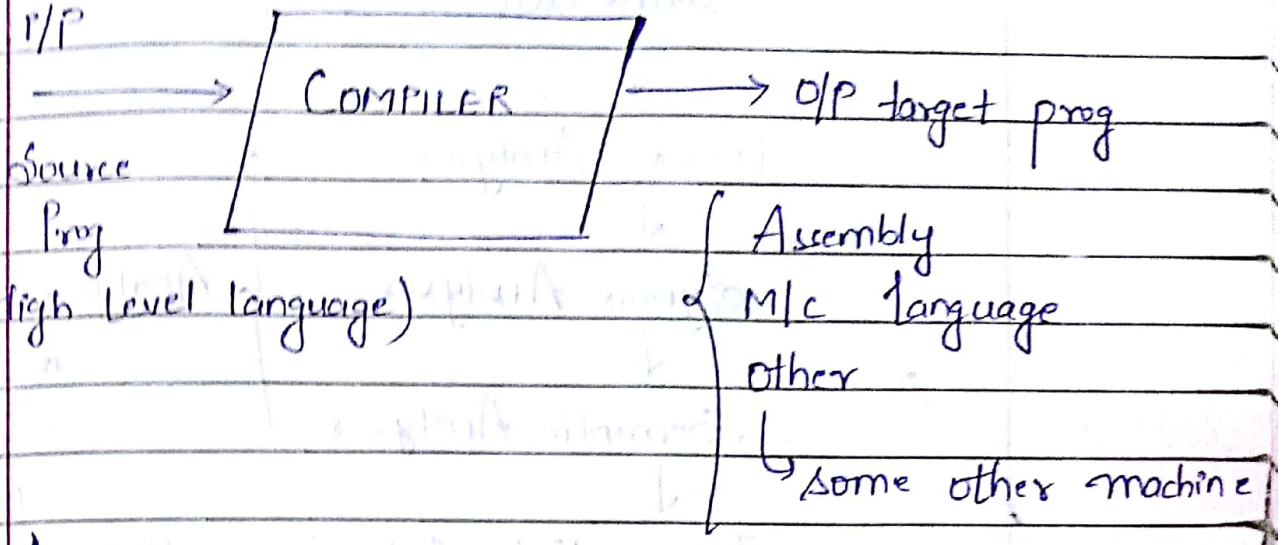


Assembly :-

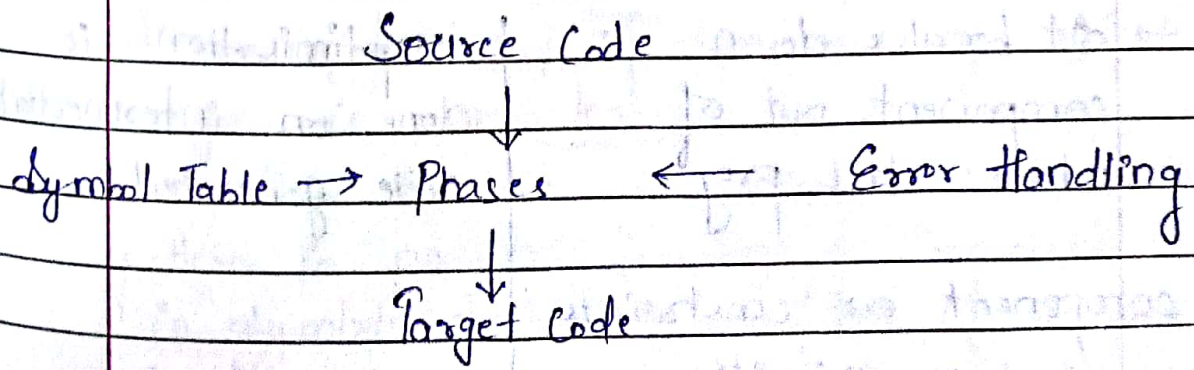
i/p → compiler → assembly language → assembler → target

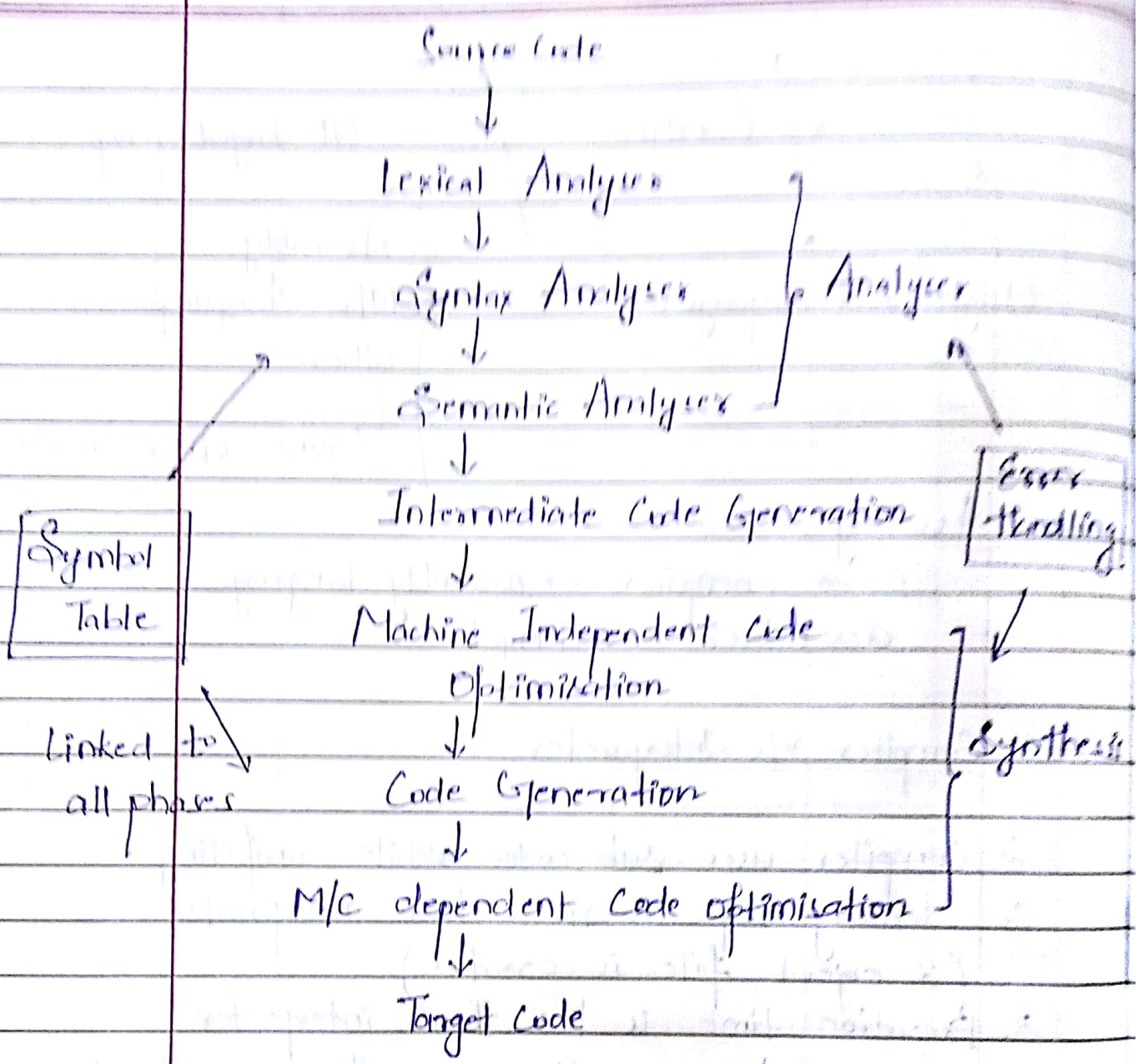
Compiler v/s Interpreter

1. Compiler uses sub codes while compiling.
2. Memory req. is more than interpreter (∵ object file is created)
3. Execution time is less than interpreter

∵ Compiler has, execution as well as compilation time & interpreter has one execution time only

PHASES OF COMPILATION





Compiler consist of 2 main phases

Compiler

Analysis Phase	Synthesis Phase
→ It breaks down components out of whole HLL prog.	→ optimisation is done on intermediate code generated.
✓ component are constraints such as int, etc. identifier, etc.	

✓ Then analysis is performed.

✓ intermediate code is generated.

position := initial + rate * 60

Analysis Phase

(1). Lexical Analysis (Linear analysis / Scanning)

```
void main ()
{
    float initial, rate, position;
    position = initial + rate * 60;
}
```

- Linear analysis :- bcz it reads each char from left to right i.e. linear scan from left to right.

→ It then converts into some meaningful token. Token are acc. to diff^n languages.

→ Symbol table contains all keyword from where token is checked during token generation.

→ A meaningful set of char read by lexical analyser is a lexeme.
Then, this lexeme is matched with existing pattern in present language & then check it in symbol table to confirm if it was a keyword.

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Eg. void matches variable name pattern but also present in Symbol Table.

∴ It is a Keyword.

→ It only validates lexeme with tokens of source language.

→ lexeme is current set checked.

→ token is stored constraints.

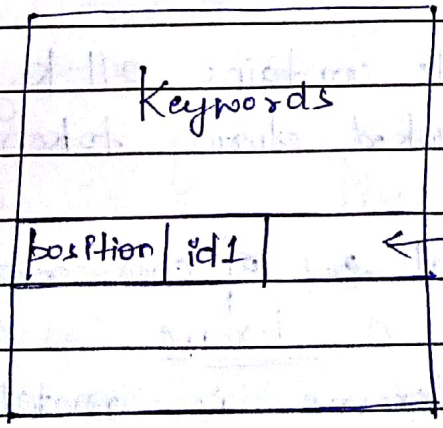
Eg. void → lexeme	; → lexeme
Keyword → token	Semicolon → token

→ (variable name)

→ As soon as a new identifier is found, it is entered in symbol table.

→ if, encountered next time, ptr is linked to that ptr stored in ST.

Symbol Table :-



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O/P of Lexical Analysis

<position, id1, ptr> → of ST

< +, plus sign>

Errors it will not report :-

main ()

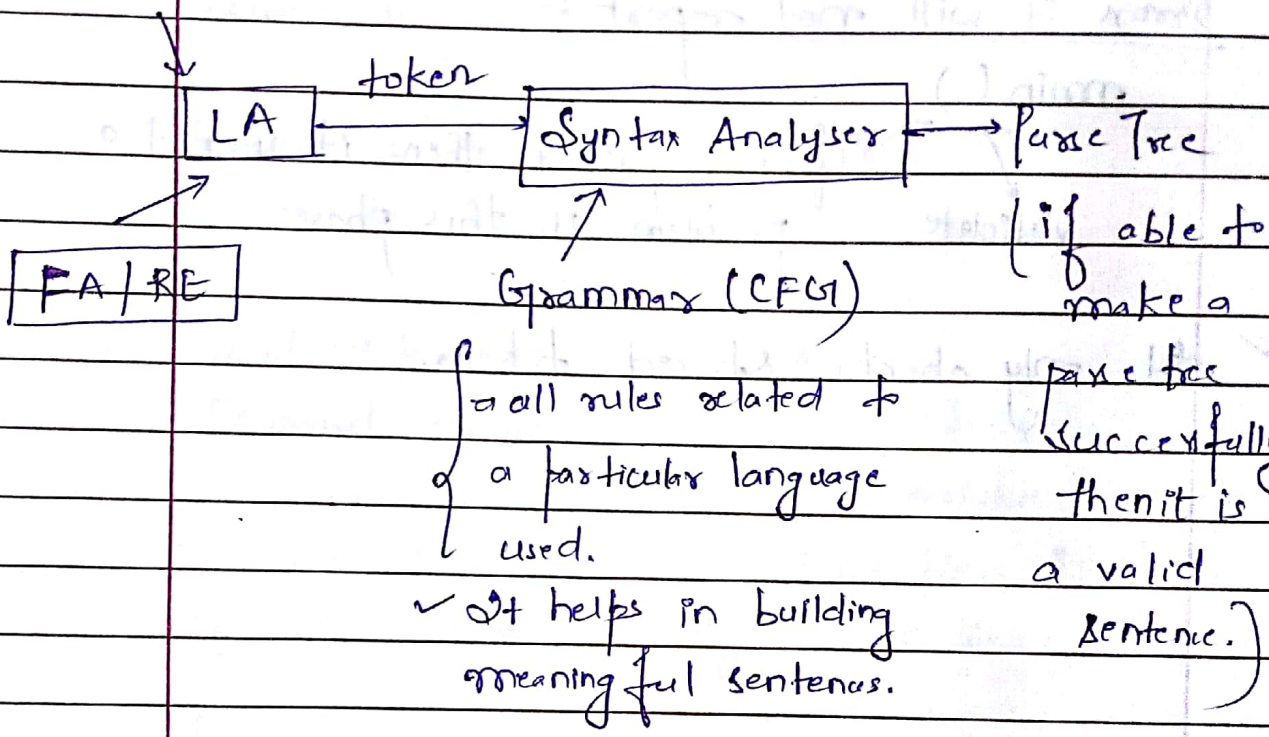
validate → if not present then it is not a problem in this phase.

- O/P only checks stored tokens.

(2). SYNTAX ANALYZER

also, Hierarchial Analysis → ∵ tree is traversed.

Parsing



Expression

1. Any identifier is an expression
2. Any number "
3. If exp_1 & exp_2 are expressions then,

$exp_1 + exp_2$
$exp_1 * exp_2$
(exp_1)
} are exp's.

Statement

1. identifier$_1$ = exp_2
2. while (exp) do stm_2

i/p string

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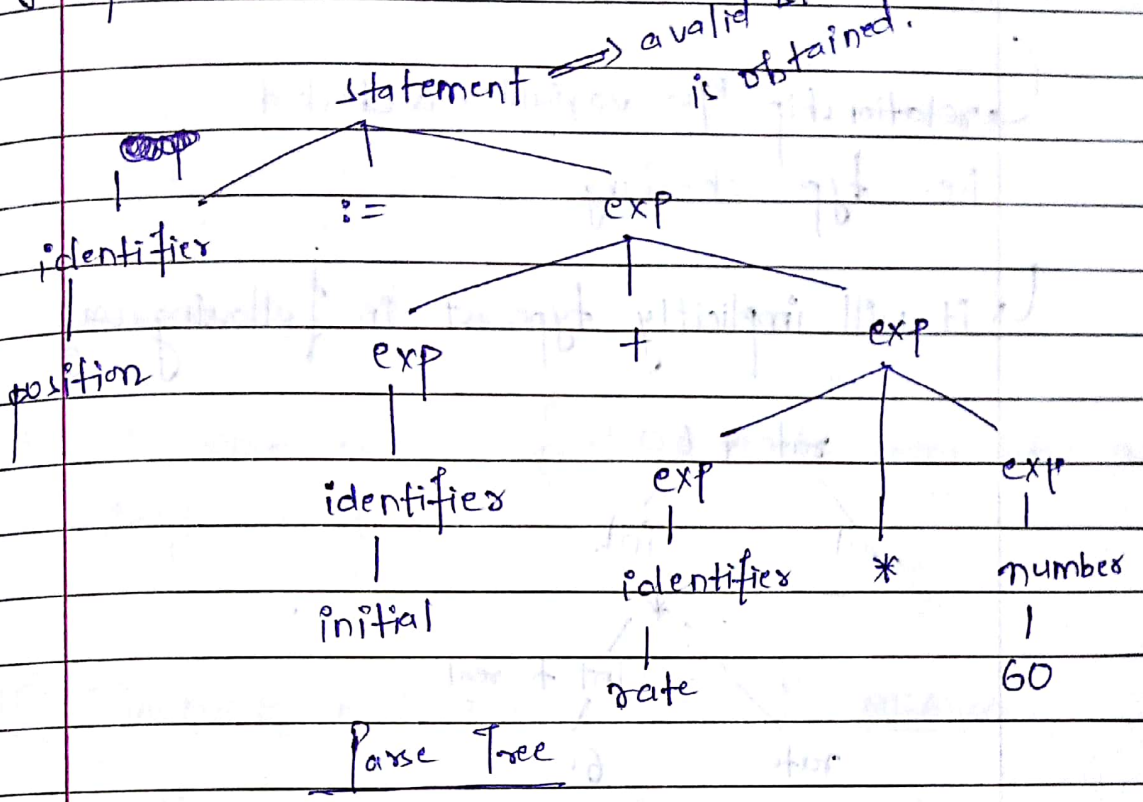
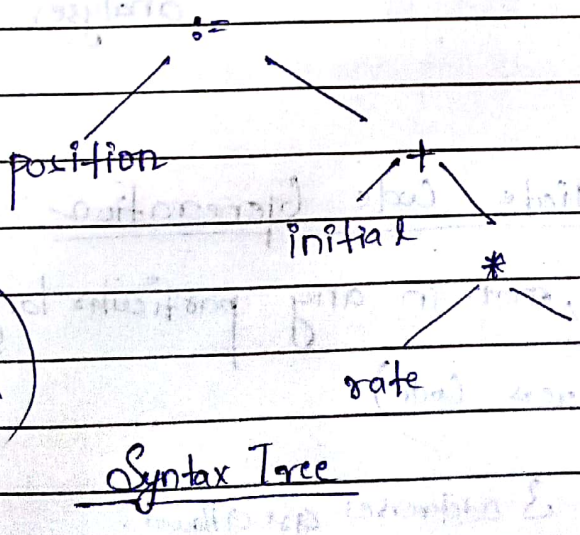
Eg. position := initial + rate * 60



Parse Tree

Compressed representation of Parse Tree is Syntax Tree.



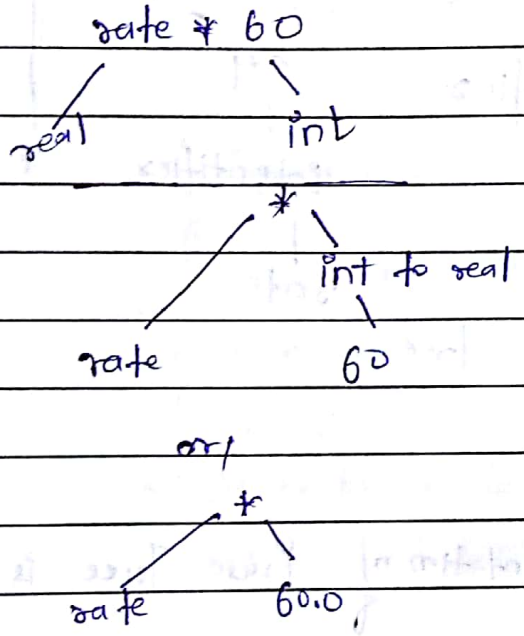
* level should be differentiated

Syntax Tree

③. Semantic Analysis

↳ relationship b/w variables is checked i.e. type checking.

↳ it will implicitly typecast in following way



(annotated Parse Tree) → o/p of Semantic analyser.

④. Intermediate Code Generation

↳ a code, not in any particular language

(3-Address Code)

↓

maximum 3 addresses are allowed.

Eg. [LHS := = + =]

① ② ③

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- Use temporary variables to ensure 3-address code

```
t1 := int to real (60)
t2 := rate * t1
t3 := initial + t2
position := t3
```

- Use temp variables freely to make computation as easy as possible.

(5). MACHINE INDEPENDENT CODE OPTIMISATION

↳ This optimisation works on all machines.

```
t1 := rate * 60.0
position := initial + t1
```

Book – ch-3

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⟹ LEXICAL ANALYSER

It also keeps new line character which helps in returning the line no. containing error.

Eg. fi (a = 6) — closing bkt
no
equal
identifier
identifier
open bkt

error handling — not matching to any pattern

Eg. abc@@# cdf

not allowed in identifier
valid
longest match

(abc) lexeme → identifier.

@@# → thrown away
cdf → again identifier

* panic mode
it will throw them.

Recovery mode

1. W panic mode recovery
2. W deleting an extra char
3. W Inserting a missing char
4. W replacing in correct char by a correct char
5. W transposing adjacent char

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Eg. 193.
matching no. but not a complete no.

∴ To continue it takes inserting a missing char recovery mode.

Eg. 123, 48
→ locally it will replace it with • to validate it.
④th recovery mode.

Eg. E 9 −4
exponent ← locally handeled. & replaced by 9 E −4
⑤th recovery mode..

Terms related to Automata.
1. Symbol → any char 0, 1, a, b, # --etc.
2. (S) Alphabet → set of symbols
3. String → finite seq of symbol
4. Language → set of strings generated by a regular expression.
5. (abc) ~~prefix~~ (n+1) if n symbols including a, ∈, ab, abc

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6. Suffix (n+1) c, bc, abc, ε

7. proper prefix ⇒ abc i.e. w ≠ string not included. (Here, w = abc)

8. proper suffix ⇒ ≠ lg.

^ *

precedence. • — concatenation
+ — union

ϕ → null set containing { }
ε → empty string.

Regular definition

regular expressions are assigned a name which is used, while writing R.E. containing those exp^n.

Eg. / ⇒ same as +

letter + digit only with first letter.

R.E. = (a|b|c|---|z|A|B|---|Z)(a|b|c|---|z|A|B|---|Z|0|1|---|9)*

(id=)

converting to definition.

letter → A|B|C---|Z|a|b|---|z
digit → 0|1|2|---|9

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Now,

identifier → letter (letter | digit)*

Eg. (number)

exponent, fraction,

digit → 0|1|--|9

sign → +|-

digits → digit digit* or (digit+)

op_fraction → ∈ | . digits

op_exp → ∈ | E(+|-|∈) digit

num → (digits /op_fraction / op_exp) (+|-|∈)

num → (+|-|∈)(digits . op_fraction . op_exp)

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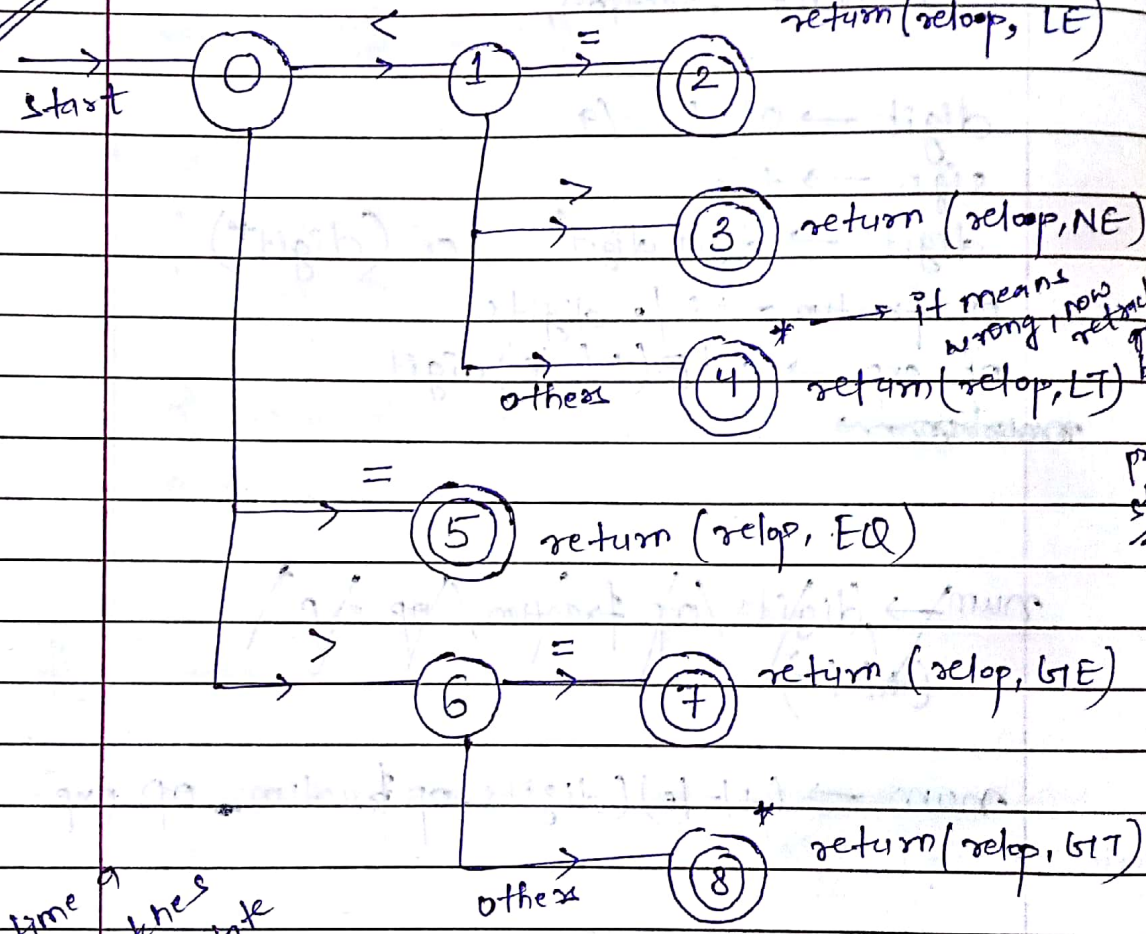
Transitional diagram

(1). relational operators allowed in pascal <, <=, >, >=, =, <> → not equal to



Every time a lexeme matches starting at state by (6).

(2). Identifier → starting with alphabets only, followed by a numeral or alphabets.

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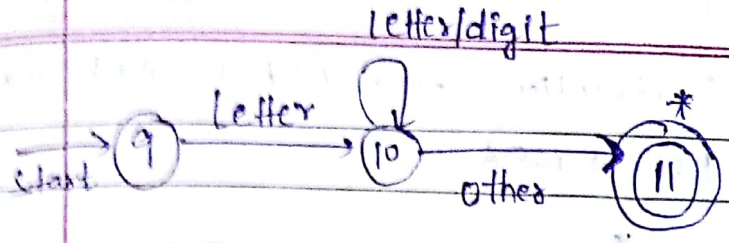
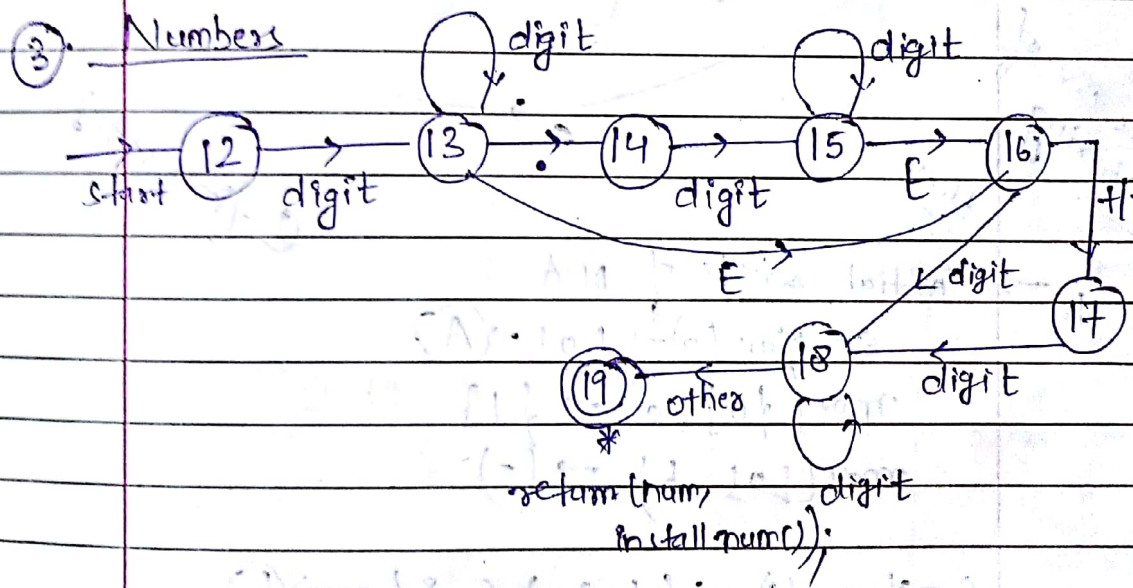
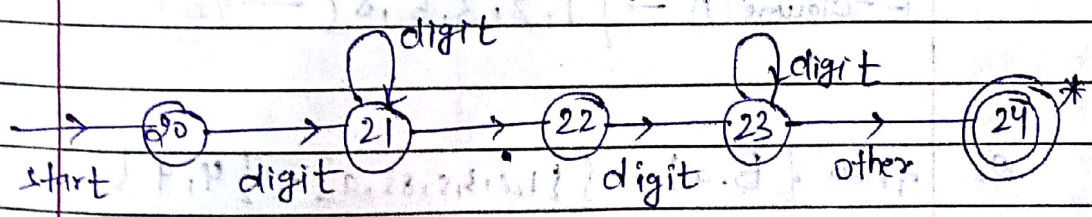
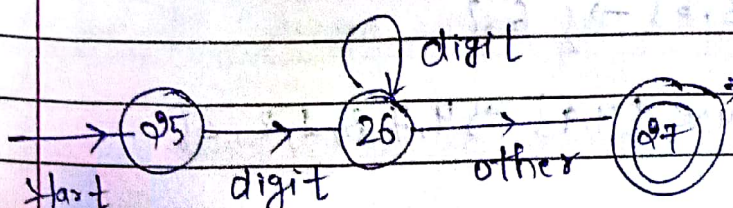


if, lexeme is a ~~token~~ keyword then, it will return install_id() as 0 else, it will make an entry and will return ptr to that entry.







* if directly mentioned then draw NFA w/o ε.

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3. Regular Expression to DFA

(a|b)* abb#

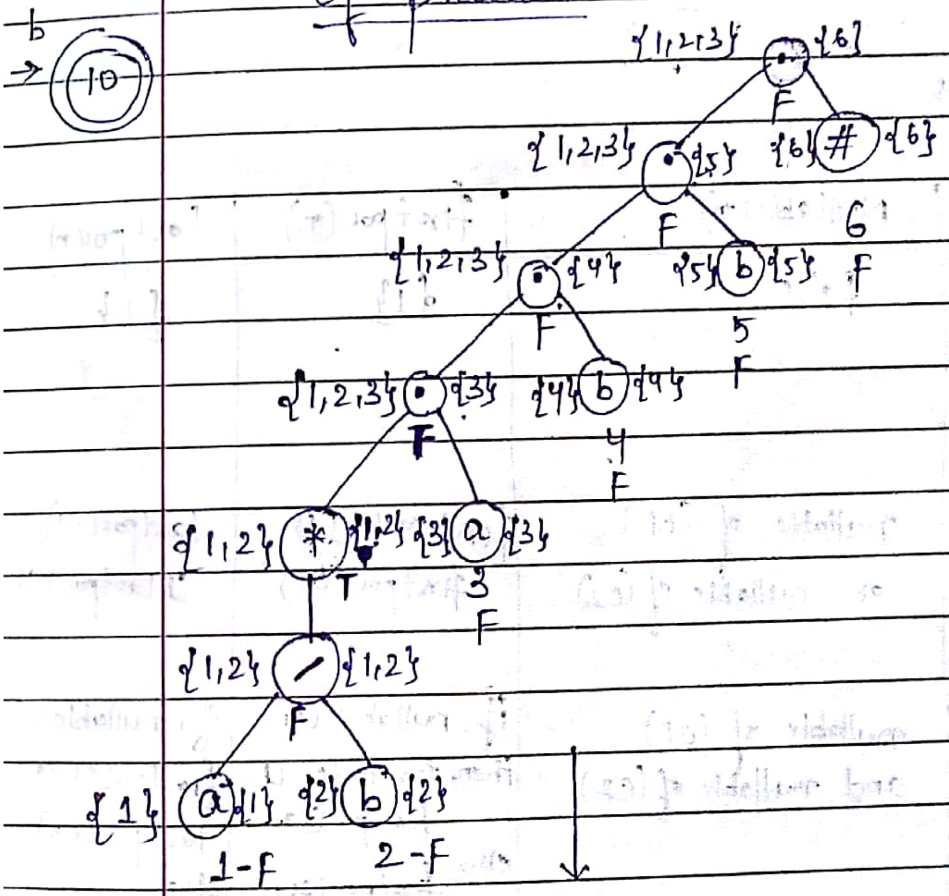
(*) follow this dir^n. if parantheses comes make it expert.

In NFA :-

⇒ States with no ε-moves are called Imp. States.

⇒ States with ε-moves are called non-Imp states.

* Step I : Make Tree by keeping in mind order of precedence



(a|b) FP ab node firstpos lastpos Tells abt nullable

d1 {1,2,3}
d2 {1,2,3}
d3 {4}
d4 {5}
d5 {6}

* Step II : Assign unique pst. to leaf nodes.

Every node (interior or exterior) is a expression.

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Step 3: Calculate following fn for the tree

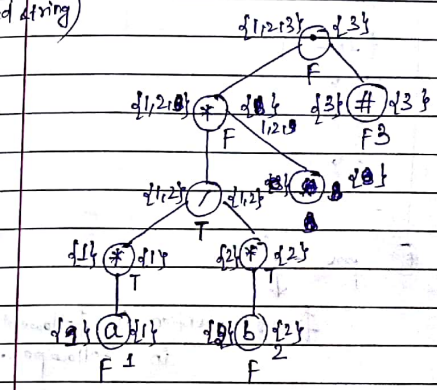
1. Nullable → calculated for each and every node
2. firstpos → calculated for each node (first symbol in generated string)
3. lastpos → " (last symbol in a generated string)
4. follow → for some nodes only.
   it belongs to ⊙ → concatenation node
   ⊛ → clear node

→ if a language generates 'ε' along with any of it is called nullable.

RULES

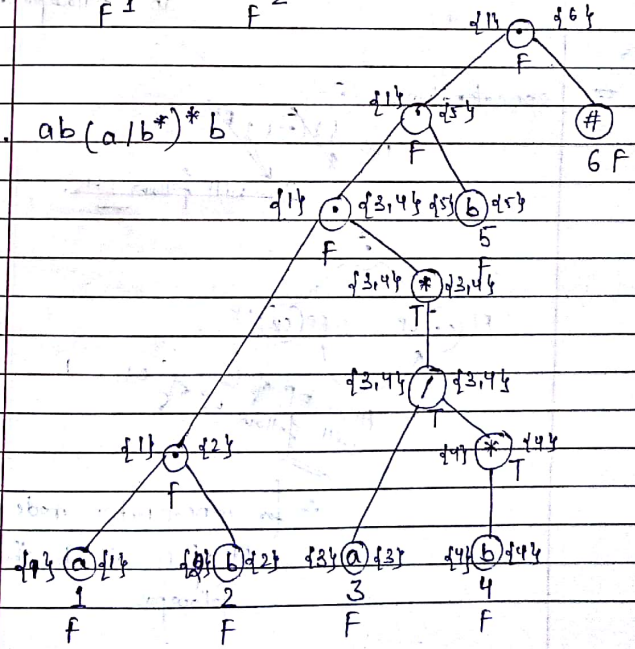
		Nullable(n)	firstpos(n)	lastpos(n)
1.	n is a leaf (labeled with ε)	false	{i}	{i}
2.		nullable of (c1) or, nullable of (c2)	firstpos(c1) ∪ firstpos(c2)	lastpos(c1) ∪ lastpos(c2)
3.		nullable of (c1) and nullable of (c2)	if, nullable (c1) then, firstpos(c1) ∪ firstpos(c2) else, firstpos(c1)	if, nullable(c2) firstpos(c1) ∪ lastpos(c2) else, lastpos(c2)
4.		True	firstpos(c)	lastpos(c)

Q. Eg. $(a^*/b^*)^*\#$



H.W.

Q. $ab(a/b^*)^*b$



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find out positions

→ follow is calculated for all nodes but they are only calculated for ⊙ and (*) nodes.

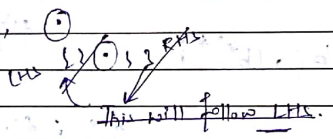
• (a|b)*abb#

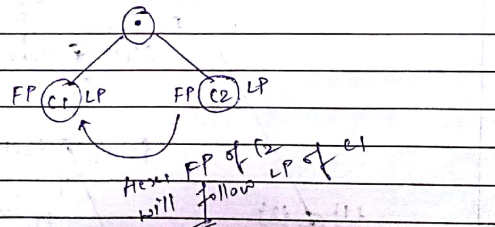
pos	follow
{1}	{1,2,3}
{2}	{1,2,3}
{3}	{4}
{4}	{5}
{5}	{6}
{6}	–

⇒ follow of (*) pos. →

first position is followed up in followpos.

⇒ concatenation, ⊙





∴ for concatenation node, LP of c2 will be the followpos.

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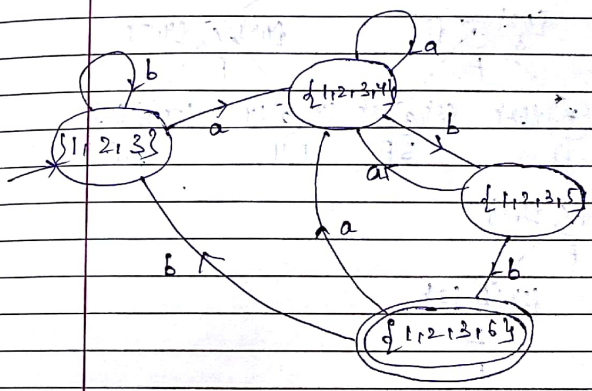
Rules :-

1. → start state of DFA, consist of all (FP) of root node.
2. To find out transition, we find that transition variable or pos included in current node or state. Then, union of all the followpos is taken.



3. Accepting state ⇒ #pos.
Here, #pos = (6).
Now, all states including #pos will have final state.

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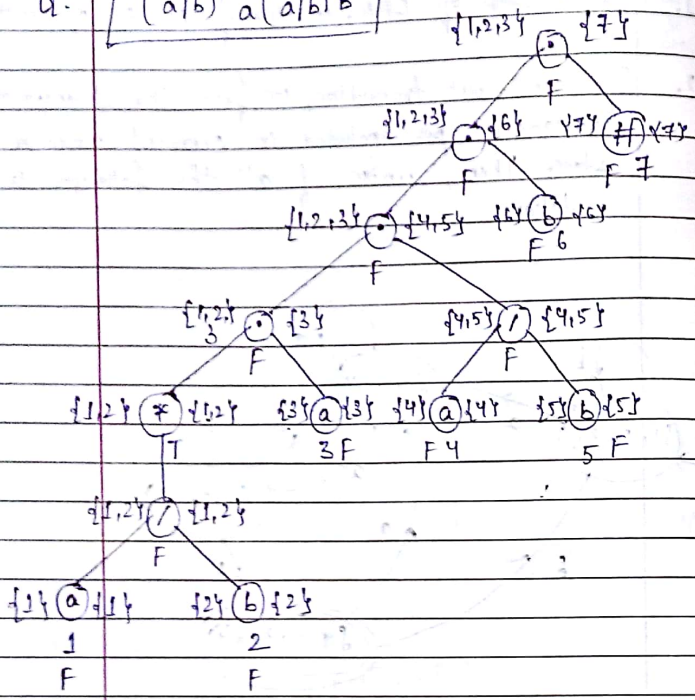
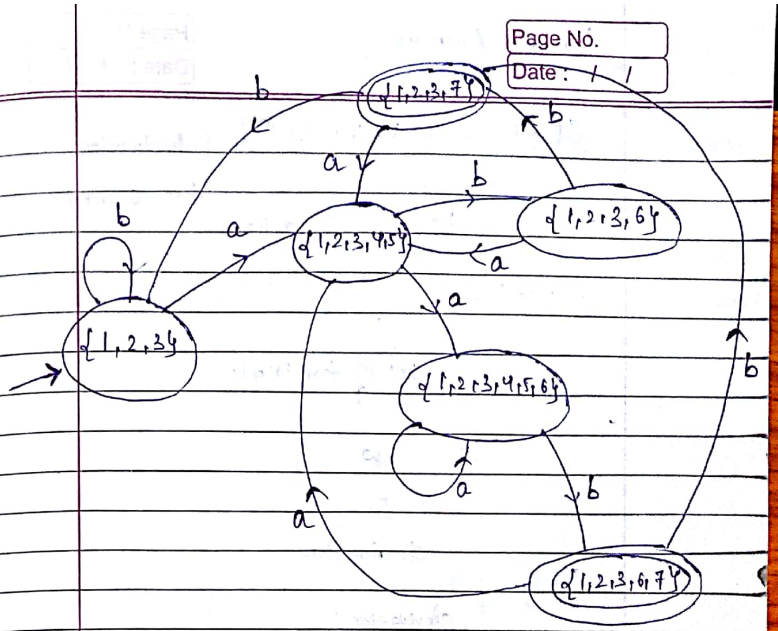
Q. $(a|b)^* a(a|b)b$



follow up

pos	follow
{1}	{1,2,3}
{2}	{1,2,3}
{3}	{4,5}
{4}	{6}
{5}	{6}
{6}	{7}
{7}	–



Syntax Analysis

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CFG, $G = \{ V, T, S, P \}$ — Production

Non-terminals, Terminals, Start Symbol

$L(G) = \{ \quad \}$

Set of terminals

$S \xrightarrow{*} w$

derivation

derivation

Leftmost, Rightmost

- Graphically derivation → Parse tree.
- Ambiguity → Leftmost or Rightmost 2 or more parse tree for same string.

$E \rightarrow E*E / E+E / (E) / -E / id$

string → $(id + id * id)$

two right most

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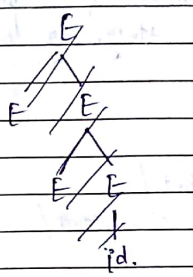
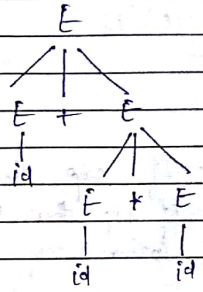
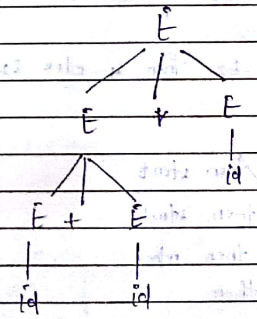
$E \rightarrow E+E \rightarrow E+E*E \rightarrow E+E*id \rightarrow E+id*id$
$\rightarrow id + id*id.$

$E \rightarrow E*E \rightarrow E*id \rightarrow E+E*id \rightarrow E+id*id$
$\rightarrow id + id*id.$







⇒ Some parsers can take ambiguous trees but, they need to have some disambiguous rules to handle it. → Hectic task.

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To handle this, we try to convert ambiguous grammar into unambiguous grammar.

Unambiguous grammar for last eg:-

$E \rightarrow E+E \mid T$ — only one left most derivation for a particular string, eg Right most

$T \rightarrow T*F \mid F$

$F \rightarrow (E) \mid id$

stmt → if exp then stmt /
if exp then stmt else stmt /
other.

non-ambiguous

(1). if E1 then (S1 else if E2 then S2 else S3.)

ambiguous

(2). if E1 then if E2 then S1 else S2.

stmt → if exp then stmt
→ if E1 then stmt
→ if E1 then other
→ if E1 then

stmt → if exp then stmt else stmt
→ if E1 then stmt. else (stmt)
→ if E1 then other else stmt
→ if E1 then S1 else stmt
→ if E1 then S1 else if exp then stmt else stmt

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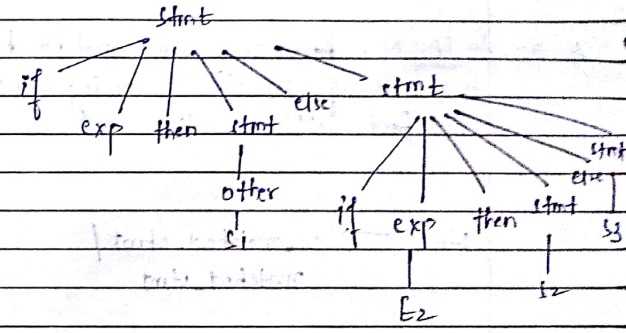
→ if E1 then S1 else if E2 then stmt else stmt

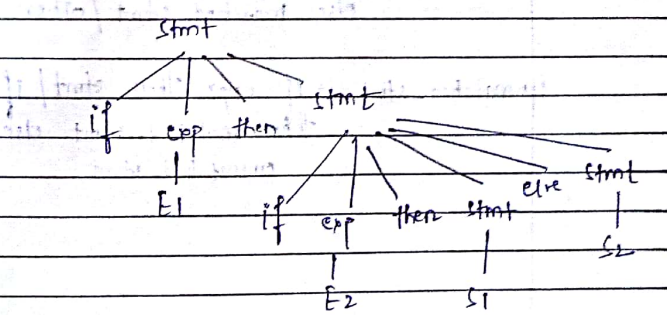
→ if E1 then S1 else if E2 then other else stmt

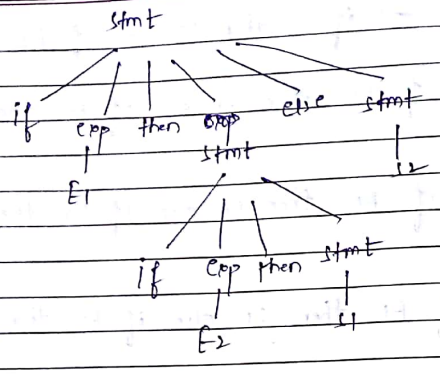
→ if E1 then S1 else if E2 then S2 else other

→ (if E1 then S1 else if E2 then S2 else S3)



(2)





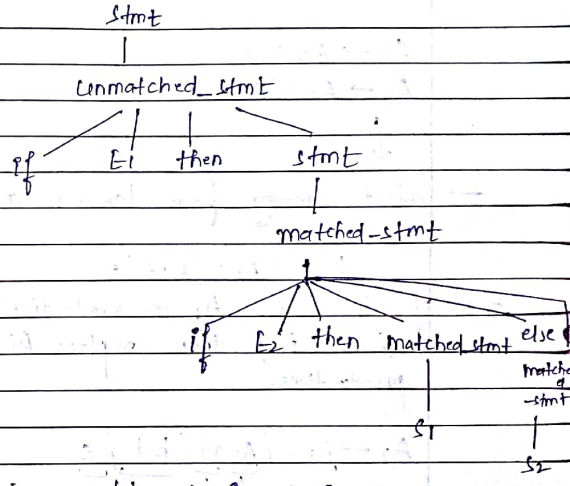
* Acc. to PASCAL, ~~last~~ every else matches to its near most if, which is coming incorrect in ~~last~~ 2nd derivation.

stmt → un_matched_stmt / matched_stmt

matched_stmt → if expr then matched_stmt else matched_stmt / other

unmatched_stmt → if expr then stmt / if expr then matched_stmt else unmatched_stmt

Eg. if E1 then if E2 then S1 else S2.



✓✓ Now, it is unambiguous grammar.

LEFT RECURSION (A → Aα/β)

* Top-Down Parser do not accept Left Recursion.
* Bottom-up Parser can accept Left Recursion.

A → β A'
A' → αA' / ε

Left-Recursion
- Immediate (Clearly visible)
- Non-Immediate (after substitution, it becomes visible.)

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Eg. $S \rightarrow A\alpha \mid b$
$A \rightarrow Ac \mid Sd \mid \epsilon$

$A_1 \rightarrow A_2 a \mid b$
$A_2 \rightarrow A_2 c \mid A_1 d \mid \epsilon$

↓

→ Start solving from lower most production.

$A_2 \rightarrow A_2 c \mid A_1 d \mid \epsilon$

** If there is A_j in production of A_i such that $i < j$ then replace A_j with its productions.

$A_2 \rightarrow \underbrace{A_2 c}_{A\alpha_1} \mid \underbrace{A_2 ad}_{A\alpha_2} \mid \underbrace{bd}_{\beta_1} \mid \underbrace{\epsilon}_{\beta_2}$

$A_2 \rightarrow bdA_2' \mid A_2'$

$A_2' \rightarrow cA_2' \mid adA_2' \mid \epsilon$

Now,

$A_1 \rightarrow A_2 a \mid b$
$A_1 \rightarrow bdA_2' a \mid A_2' a \mid b$

$A_1 \rightarrow bdA_2' a \mid A_2' a \mid b$
$A_2 \rightarrow bdA_2' \mid A_2'$
$A_2' \rightarrow cA_2' \mid adA_2' \mid \epsilon$

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(ii) $A' \rightarrow \alpha'$

LEFT FACTORING

stmt - if exp then stmt else stmt /
if exp then stmt

If 2 productions have common part
α = if exp then stmt

stmt $\rightarrow \alpha\beta_1 / \alpha\beta_2$ { we left factor this grammar }

$A \rightarrow \alpha\beta_1 / \alpha\beta_2 \longrightarrow A \rightarrow \alpha A'$
$A' \rightarrow \beta_1 / \beta_2$

Decision of which production to choose is deferred for future.

Top-Down Parser

(i) left recursion is removed
(ii) left factoring is done

(1) $E \rightarrow E+T / T$
$T \rightarrow T * F / F$
$F \rightarrow (E) / id$

A. $T \rightarrow \underbrace{T * F}_{\alpha_1} / \underbrace{F}_{\beta_1}$ (left recursion)

$T' \rightarrow \alpha F T' / \varepsilon$
$T \rightarrow F T'$

$E \rightarrow E + T / T$

$E \rightarrow TE'$

$E' \rightarrow +TE' / \varepsilon$

$F \rightarrow (E) / id$

(a) $A \rightarrow Ba / c$

$B \rightarrow AA$

$C \rightarrow B / b$

Ans. $A_1 \rightarrow A_2 a / A_3$

$A_2 \rightarrow A_1 A_1$

$A_3 \rightarrow A_2 / b$

$A_2 \rightarrow A_1 A_1$

$\downarrow$

$A_2 \rightarrow A_2 a A_1 / A_3 A_1$

$\downarrow$

$A_2 \rightarrow A_3 A_1 A_2'$

$A_2' \rightarrow a A_1 A_2' / \varepsilon$

$A_3 \rightarrow A_2 / b \rightarrow A_3 \rightarrow A_3 \rightarrow A_3 \underbrace{A_1 A_2'}_{\alpha} / \underbrace{b}_{\beta}$

$A_3 \rightarrow b A_3'$

$A_3' \rightarrow A_1 A_2' A_3' / \varepsilon$

$A_1 \rightarrow A_2 a / A_3$

$A_2 \rightarrow A_3 A_1 / A_2'$

$A_2' \rightarrow a A_1 A_2' / \varepsilon$

$A_3 \rightarrow b A_3'$

$A_3' \rightarrow A_1 A_2' A_3' / \varepsilon$

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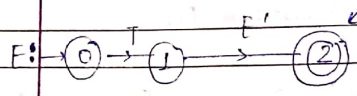
Example of Predictive Parser

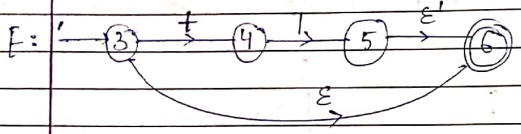
* Imp

$E \rightarrow TE'$

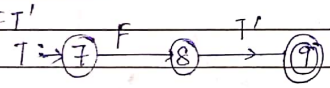
declare accept on reaching this state.



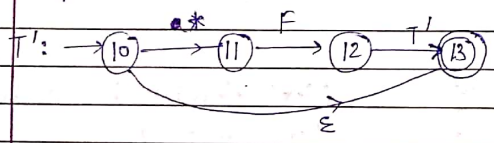
$E' \rightarrow +TE' / \varepsilon$



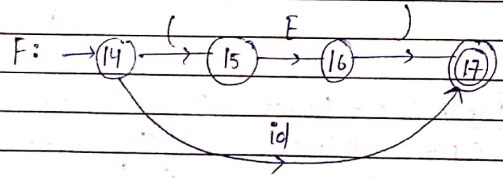
$T \rightarrow FT'$



$T' \rightarrow *FT' / \varepsilon$



$F \rightarrow (E) / id$



if transition for non-terminals, we jump to procedure of that terminal.

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id + id * id

State 0 → State 7 → State 14 → 17 → END

Diagram of T | Diagram of F | END

Move back in recursion

→ State 8 → State 10 → State 13 →

Diagram of T' | END

→ State 9 → State 1 → State 3 → State 4

END | Diagram of E'

→ State 7 → State 14 → 17 → State 8 → State 10 →
→ State 11 → State 14 → State 17 → State 12 → State 10
→ State 13
END

END

AND SO ON.

* Imp

Remove left recursion by factoring it left factoring is present in predictive parser.

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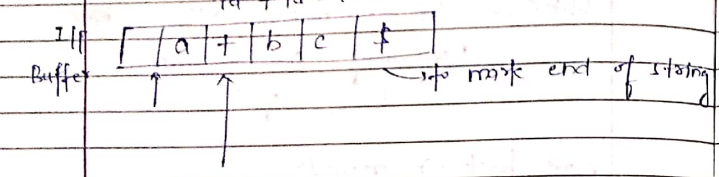
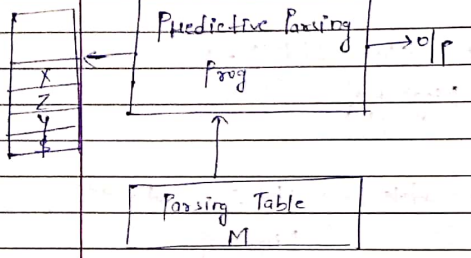
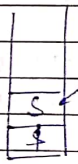
NON-RECURSIVE PREDICTIVE PARSER

id + id * id





initially,



E → TE'
E' → +TE' / ∈
T → FT'
T' → *FT' / ∈
F → (E) / id

Calculate FIRST for each terminals as well as non-terminals.

Friday - Test

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FOLLOW is calculated only for non-terminals.

HP FIRST of a non-terminal is the first terminal of string of terminals i.e. sentence derived from it.

FIRST of terminal is a terminal.
" " ∈ is ∈

Eg. A → ab / ∈ / BC

FIRST of A will include, a and first of B, if B is ∈ then first of C.

** RULES:

1. If X is a terminal first(X) = {X}
2. If X → ∈, first(X) → {∈}
3. X → Y1 Y2 — Yn

FIRST(X) → FIRST(Y1) ∪ FIRST(Y2) — ∪ FIRST(Yn) until, ∈ is there in Yi.

FIRST(E) = {(, id}	FOLLOW(E) = {$,)}
FIRST(E') = {+, ∈}	FOLLOW(E') = {$,)}
FIRST(T) = {(, id}	FOLLOW(T) = {+, *, $,)}
FIRST(T') = {*, ∈}	FOLLOW(T') = {+, $,)}
FIRST(F) = {(, id}	FOLLOW(F) = {*, +, $,)}

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** Rules for follow :

1. S → start Symbol ; Follow (S) = { $ }
2. A → αBβ
   follow (B) → first (β) U Follow (A)
   ↓ if β contains ∈
   i.e. A → αB
   then, follow (B) → Follow (A)

   (if, A → αBβ
   follow of B i.e. first (β) contains ∈
   then follow (A) also.)

* PARSING TABLE :-

Terminals →

Non terminals ↓	id	+	*	(	)	$
E	E → TE'			E → TE'		
E'		E' → +TE'			E' → ∈	E' → ∈
T	T → FT'			T → FT'		
T'		T' → ∈	T' → *FT'		T' → ∈	T' → ∈
F	F → id			F → (E)		

** Rules

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How to fill Parsing table :

- Take one production at a time.
- A → α
  in row of 'A', write production A → α in all terminals of first (α).
  if, α contains ∈ or production is A → ∈ then,
  also, all terminals of follow (A)
- A → terminal α.
  ↓
  production in terminal col.
- ~~write~~ accept in $ of start symbol.

* [Part reverse string in stack

Stack	I/P string
$E	id + id * id $
$E'T	id + id * id $
$E'T'F	id + id * id $
$E'T'id	id + id * id $
$E'T'	+ id * id $
$E'	+ id * id $
$ E'T+	+ id * id $

R → (E)
C → (

A → BC

$ E'T	id * id $
$ E'T'F	id * id $
$ E'T' id	id * id $
$ E'T'	* id $
$ E'T'F *	* id $
$ E'T'F	id $
$ E'T' id	id $
$ E'T'	$
$ E'	$
$	$

→ accepted string

✓ Grammar Generated is LL(1) — Parser; no. of look ahead symbol

left Scanning is done

left most derivate tree

Q. ① S → iEtSS' | a
S' → eS | ∈
E → b

② S → [SX] | a
X → +SY | Yb | ∈
Y → SXc | ∈

① S → iEtSS' | a
S' → eS | ∈
E → b

FIRST(S) = { i, a }	FOLLOW(S) = { $, e }
FIRST(S') = { e, ∈ }	FOLLOW(S') = { $, e }
FIRST(E) = { b }	FOLLOW(E) = { t }

PARSING Table :-

Terminals →

Non-terminals ↓	i	t	a	e	b	$
S	S→iEtSS'		S→a			
S'				S'→eS, S'→∈		S'→∈
E					E→b	

Stack	I/P string
$ S	S →

LMP

∵ two production are there, ⇒ ambiguity ⇒ not a LL(1) grammar ⇒ fails.

$X \to Yb$

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(2). $S \to [SX] \mid a$
$X \to +SY \mid Yb \mid \epsilon$
$Y \to SXc \mid \epsilon$

FIRST(S) = {[, a}	FOLLOW(S) = {$, +, [, a, b,], c}
FIRST(X) = {+, ε, [, a, b}	FOLLOW(X) = {], c}
FIRST(Y) = {ε, [, a}	FOLLOW(Y) = {], b, c}

Parsing Table :

	[	]	a	+	b	c	$
S	S→[SX]		S→a				
X	X→Yb	~~X→ε~~ X→ε	X→Yb ✓	X→+SY ✓	X→Yb	~~X→ε~~ X→ε	
Y	Y→SXc	Y→ε	Y→SXc		Y→ε	Y→ε	

* IMP Rule :-

$X \to \alpha\beta$...
if, α contains ε then, we'll put this production in first of further non-terminals or terminals.

[ab]

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$ S	[ab]$
$ [SX]	[ab]$
$ [SX	ab]$
$ [S	Xb]$
$ [a	Xb]$
$ X]	b]$
$ Yb]	b]$
$ b]	b]$
$]	]$
$	$

→ accepted.

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Questions

(1). $S \to A$

$A \to aB \mid Ad$

$B \to bBC \mid f$

$C \to g$

String (abfa)

FIRST(S) = {a}	FOLLOW(S) = {$}
FIRST(A) = {a}	FOLLOW(A) = {d, $} (S, A)
FIRST(B) = {b, f}	FOLLOW(B) = {g, d, $} (A, B) (X)
FIRST(C) = {g}	FOLLOW(C) = {g, d, $} (B)

	a	d	b	f	g	$
S	S→A					
A	A→aB A→Ad					
B						
C						

Imp.

LL-parser → left Recursion & left factoring

remove

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Q1. $S \to A$

$A \to aB \mid Ad$

$B \to bBC \mid f$

$C \to g$

w String (abfg)

$A \to \underset{\alpha}{Ad} \mid \underset{\beta}{aB}$

$A' \to aBA'$

$A' \to dA' \mid \epsilon$

$S \to A$

$A \to aBA'$

$A' \to dA' \mid \epsilon$

$B \to bBC \mid f$

$C \to g$

FIRST(S) = {a}

FIRST(A) = {a}

FIRST(A') = {d, ε}

FIRST(B) = {b, f}

FIRST(C) = {g}

FOLLOW(S) = {$}

FOLLOW(A) = {$}

FOLLOW(A') = {$}

FOLLOW(B) = {d, g, $}

FOLLOW(C) = {d, g, $}

	a	b	d	f	g	$
S	S→A					
A	A→aBA'					
A'			A'→dA'			A'→ε
B		B→bBC		B→f		
C					C→g	

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String :

abfg

Stack	I/P
$S	abfg$
$A	abfg$
$A'Bf	abfg$
$A'B	bfg$
$A'CBb	bfg$
$A'CB	fg$
$A'Cf	fg$
$A'C	g$
$A'g	g$
$A'	$
$	$

→ accepted

Q2. E → UV | EBE | V | [E]

V → a | b

U → < | >

B → ? | ! | @

string : a@a!a

Ambiguous or not.

a@a!a

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Q2 left most

$E \to EBE \to VBE \to aBE \to a@E$

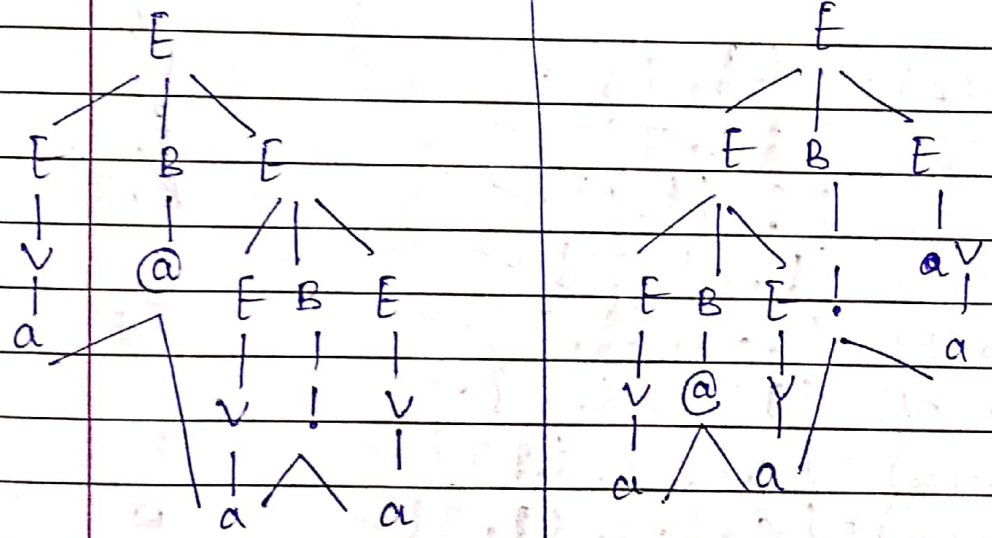
$\to a@EBE \to a@VBE \to a@aBE$

$\to a@a!E \to a@a!V \to \boxed{a@a!a}$

$E \to EBE \to EBEBE \to VBEBE \to aBEBE$

$\to a@EBE \to a@VBE \to a@aBE$

$\to a@a!E \to a@a!V \to \boxed{a@a!a}$



Q3. $E \to TE'$

$E' \to ?E \mid \epsilon$

$T \to FT'$

$T' \to !T \mid \epsilon$

$F \to WF'$

$F' \to @F \mid \epsilon$

$W \to UV \mid V \mid [F]$

$V \to a \mid b$ or

$U \to <\!/\!>$

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FIRST(E) = { [, < , a , b , ? } ✓
FIRST(E') = { ? , ϵ } ✓
FIRST(T) = { [, < , a , b , ? } ✓
FIRST(T') = { ! , ϵ } ✓
FIRST(F) = { [, < , a , b , ? } ✓
FIRST(F') = { @ , ϵ } ✓
FIRST(W) = { [, < , a , b , ? } ✓
FIRST(V) = { a , b } ✓
FIRST(U) = { < } ✓

Follow(E) = { $,] } ✓ — E'
Follow(E') = { $,] } ✓ — E,
Follow(T) = { ? , $,] } ✓ — E, T'
Follow(T') = { ? , $,] } ✓
Follow(F) = { ! , ? , $,] } ✓ — T, F'
Follow(F') = { ! , ? , $,] } ✓
Follow(W) = { @ , ! , ? , $,] } ✓ — F
Follow(V) = { @ , ! , ? , $,] } ✓ — W
Follow(U) = { a , b } ✓

	?	!	@	[	]	a	b
E				E→TE'		E→TE'	E→T
E'	E'→?E				E'→ϵ		
T				T→F¬T'		F¬F¬T'	T→F
T'	T'→ϵ	T'→!T			T'→ϵ		
F				F→WF'		F→WF'	F→W
F'	F'→ϵ	F'→ϵ	F'→@F		F'→ϵ		
W				W→[E]		W→V	W→
V						V→a	V→
U							

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FIRST(E) = { [, <, a, b, } ✓
FIRST(E') = { ?, ϵ } ✓
FIRST(T) = { [, <, a, b, } ✓
FIRST(T') = { !, ϵ } ✓
FIRST(F) = { [, <, a, b, } ✓
FIRST(F') = { @, ϵ } ✓
FIRST(W) = { [, <, a, b, } ✓
FIRST(V) = { a, b } ✓
FIRST(U) = { <, } ✓

FOLLOW(E) = { $,] } ✓ E'
FOLLOW(E') = { $,] } ✓ E
FOLLOW(T) = { ?, $,] } ✓ E, T'
FOLLOW(T') = { ?, $,] } ✓
FOLLOW(F) = { !, ?, $,] } ✓ T, F'
FOLLOW(F') = { !, ?, $,] } ✓
FOLLOW(W) = { @, !, ?, $,] } ✓ F
FOLLOW(V) = { @, !, ?, $,] } ✓ W
FOLLOW(U) = { a, b } ✓

	?	!	@	[	]	a	b
E				E→TE'		E→TE'	E→TE'
E'	E'→?E				E'→ϵ		
T				T→FT'		T→FT'	T→FT'
T'	T'→ϵ	T'→!T			T'→ϵ		
F				F→WF'		F→WF'	F→WF'
F'	F'→ϵ	F'→ϵ	F'→@F		F'→ϵ		
W				W→[E]		W→V	W→V
V						V→a	V→b
U							

a@a!a

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Stack	I/P
$E	$a@a!a$
$E'T	a@a!a$
$E'T'F	a@a!a$
$E'T'F'ω	a@a!a$
$E'T'F'V	a@a!a$
$E'T'F'A	A@a!a$
$E'T'F'	@a!a$
$E'T'F@	@a!a$
$E'T'F	a!a$
$E'T'F'ω	a!a$
$E'T'F'V	a!a$
$E'T'F'A	A!a$
$E'T'F'	!a$
$E'T'	!a$
$E'T'!	!a$
$E'T	a$
$E'T'F	a$
$E'T'F'ω	a$
$E'T'F'V	a$
$E'T'F'A	A$
$E'T'F'	$
$E'T'	$
$E'	$
$	$

→ string accepted

<	>	$
E→TE'	E→TE'	
		E'→∈
T→FT'	T→FT'	
		T'→∈
F→ωF'	F→ωF'	
		F'→∈
ω→UV	ω→UV	
U→<	U→>	

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Q.4 $S \to X|b$
$X \to S|a$
] left recursion.

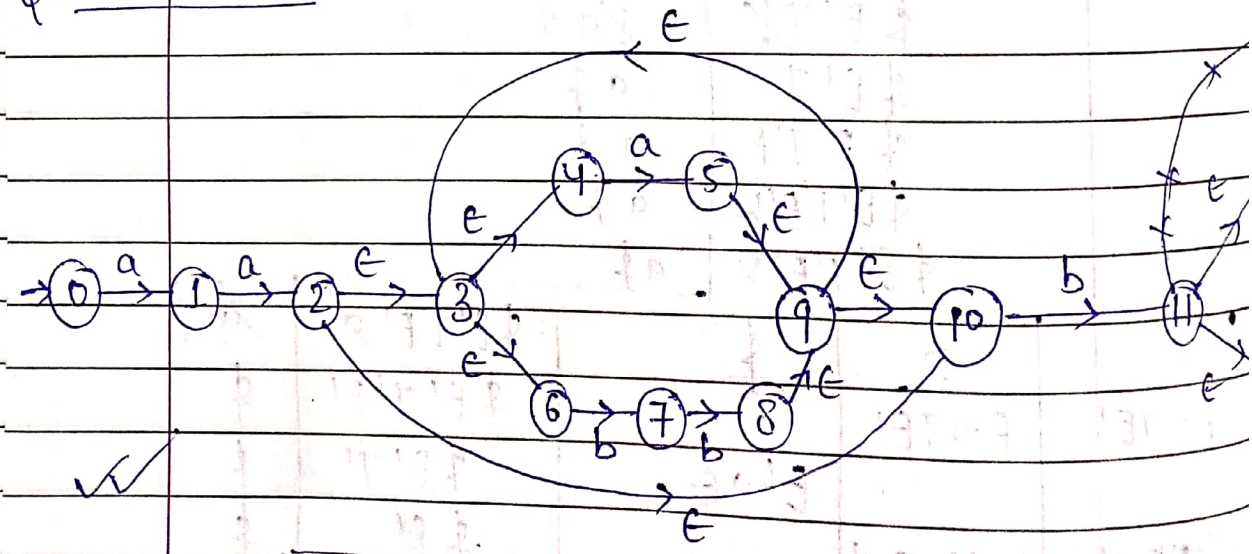
Q. $aa(a|bb)^*b(a|b)$ — Thompson

LL-Parser :-

Q. SLR, 1. $F \to id(P);$
$P \to Pf\ id | id$

2. $T \to B | \{L\}$
$L \to TL | B$
$B \to a|b.$

Q. THOMPSON :



$(aa(a|bb)^*b(a|b)$

Que DFA — from NFA
— direct algo (Parse
— direct from mind

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Q4. Left-Recursion

$S \to X \mid b$
$X \to S \mid a$

$A_1 \to A_2 \mid b$
$A_2 \to A_1 \mid a$

$A_1 \to A_2 \mid b$
$A_2 \to A_2 \mid b \mid a$

$A_1 \to A_2 \mid b$
$A_2 \to b \mid a$