Automata

Unit - 2

Grammar :- It is a finite set of formal rules for generating syntactically correct sentences or meaningful correct sentences.

Regular Grammar :- It tells what all rules we apply to get string from R.L / R.E.

Regular Grammar
↓
RL + R.E + $\underbrace{\text{DFA} + \text{NFA}}_{\text{FA}}$

$a^n b^n$ → R.L
aabb → string
$(aa^*)b$ → R.E

Formal definition of Grammar :-
Any Grammar is a 4-tuples $G = (V_T, V_N, P, S)$

V_T → Set of ~~non~~ terminals
V_N → Set of non-terminals
P → Production Rules
S → Start Symbol.

Terminal → Those which are component of sentences generated by grammar represented by small case letter like a, b, c, etc.
Non-Terminal → Those which take part in generation of sentence but not component of sentence. represented by capital letter like A, B, S, etc.

Production Rule :- It is a rewrite rule specifying a symbol substitution that can be recursively performed to generate new symbol sequence.

Eg. $P = \begin{cases} S \to aSb \\ S \to ab \end{cases}$

$S \to aSb$

$S \to aabb$.

Q $P = \{ A \to Aa,\ A \to AAa,\ A \to a,\ A \to \epsilon$
Find all tuples.

$S \to \{A\}$

Non Terminal $V_N = \{A\}$

Terminal $V_T = a$,

Language for this → any combination of a.

R.E → a^*

[If $A \to \epsilon$ would not be there then R.E → a^+]

R.G vs CFG :-

Type-4
↓
R.G
↓
Regular Grammar
↓
R.L
↓
R.E
↓
FA

Type-3
↓
CFG
↓
Context free Grammar
↓
Push Down Automata
↓
$a^n b^m$. $n = m$, $n > m$, $n < m$

CFG (Context Free Grammar) :-

A Context-free Grammar is a notation for describing language. It is more powerful than finite automata or R.E. It is a recursive method of specifying grammar rules which can generate string in a language.

Q
$S \rightarrow AB$
$A \rightarrow a$
$B \rightarrow b$

$V_N = \{S, A, B\}$
$V_T = \{a, b\}$

Q
$S \rightarrow Aa$
$A \rightarrow a$

$V_N = \{S, A\}$
$V_T = \{a\}$

* If there is 2 Non-Terminal in right side of production Rule, Then it can not be a Regular Grammar. e.g. $S \rightarrow AB$.

Q. Construct CFG for the language having any number of a's over the set $\Sigma = \{a\}$.

Sol → As we know R.E of the language is a^*.

$S \rightarrow aS$
$S \rightarrow \epsilon$

Q Construct CFG for following regular Expression :-

1) $(a+b)^* ab (a+b)^*$

$S \rightarrow A ab A$
$A \rightarrow \epsilon / aA / bA$

$V_N \rightarrow S, A$
$V_T \rightarrow a, b$

2) ww^r $\quad$ $\underline{abab}$ ✗ $\quad$ $\underline{abba}$ ✓

String that can be generated by this is
aa, bb, ~~aabb~~, abba, aabbaa, ...

$S \rightarrow aSa$
$S \rightarrow bSb$
$S \rightarrow \epsilon$

3) wcw^r :-

String that can be accepted by this is
bcb, aca, aacaa, abcba, ...

$S \rightarrow aSa$
$S \rightarrow bSb$
$S \rightarrow c$

Generating aabcbaa from this

$S \rightarrow aSa$
$S \rightarrow aaSaa$ $[\because S \rightarrow aSa]$
$S \rightarrow aabSbaa$ $[\because S \rightarrow bSb]$
$S \rightarrow aabcbaa$ $[\because S \rightarrow c]$

4. $L = \{ab(bbaa)^n bba(ba)^n\}$

Sol →
$S \to abAbbaB$
$A \to bbaaA \mid \epsilon$
$B \to baB \mid \epsilon$

5. $L = a^n b^{2n}$ where $n \geq 0$

$S \to aSbb$	$S \to aAbb \mid \epsilon$
$S \to \epsilon$	$A \to \epsilon \mid aAbb$

Both are correct

Note → We can have different production rule for a language.

6. $a^{2n} b^m$ $n>0, m>0$.

$S \to aaAB$
$A \to aaA \mid \epsilon$
$B \to bB \mid \epsilon$

Generate aaaaaa bbb using the result

$S \to aaAB$
$aaaaAbB$ [$\because A \to aaA, B \to bB$]
$aaaaaaAbbB$ [$\because A \to aaA, B \to bB$]
$aaaaaaAbbbB$ [$\because B \to bB$]
$aaaaaabbb$ [$\because A \to \epsilon, B \to \epsilon$]

Types of Grammar :-

There are 4 types of Grammar :-

1) Type - 0 → Turing Machine
2) Type - 1 → Linear Bounded automata
3) Type - 2 → PushDown Automata
4) Type - 3 → Finite State Automata.

Type 3 :-

$S \rightarrow aS / a$
$S \rightarrow Sa / a$

⇒ 1 Non-terminal

Type 2 :-

$A \rightarrow B$ → can be any string.

↑ only 1 Non-terminal

Eg. $A = aSb \rightarrow CFG$

$S \rightarrow aSaB$ $\quad S \rightarrow aSbS \rightarrow CFG$

$S \rightarrow \epsilon, B \rightarrow ab$ $\quad A \rightarrow aAbB$ → CFG $\quad A \rightarrow a, A \rightarrow aA$

$A \rightarrow a$ → RG + CFG, $A \rightarrow aA$ → RG + CFG

Type 1 :-

$A \rightarrow B$

↑ any string ↑ string as long as or longer than A.

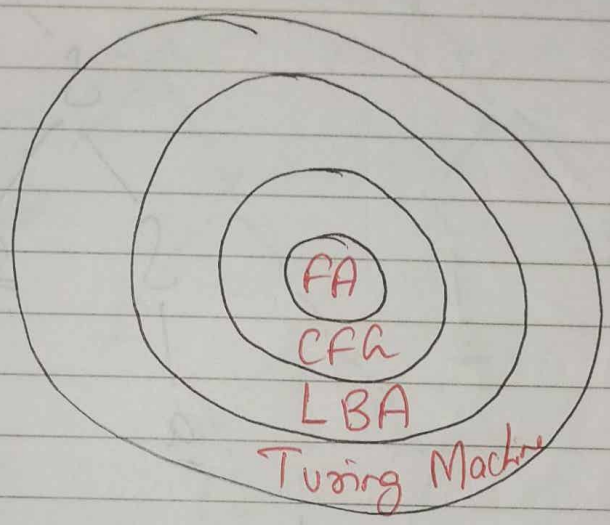
Eg :- $A \rightarrow AB$

$AI \rightarrow ABIC$

Type 0 :- $A \rightarrow B$

any string any string

Eg. $ABS \rightarrow AB$
$AB \rightarrow AC$



Ambigous Grammar :-

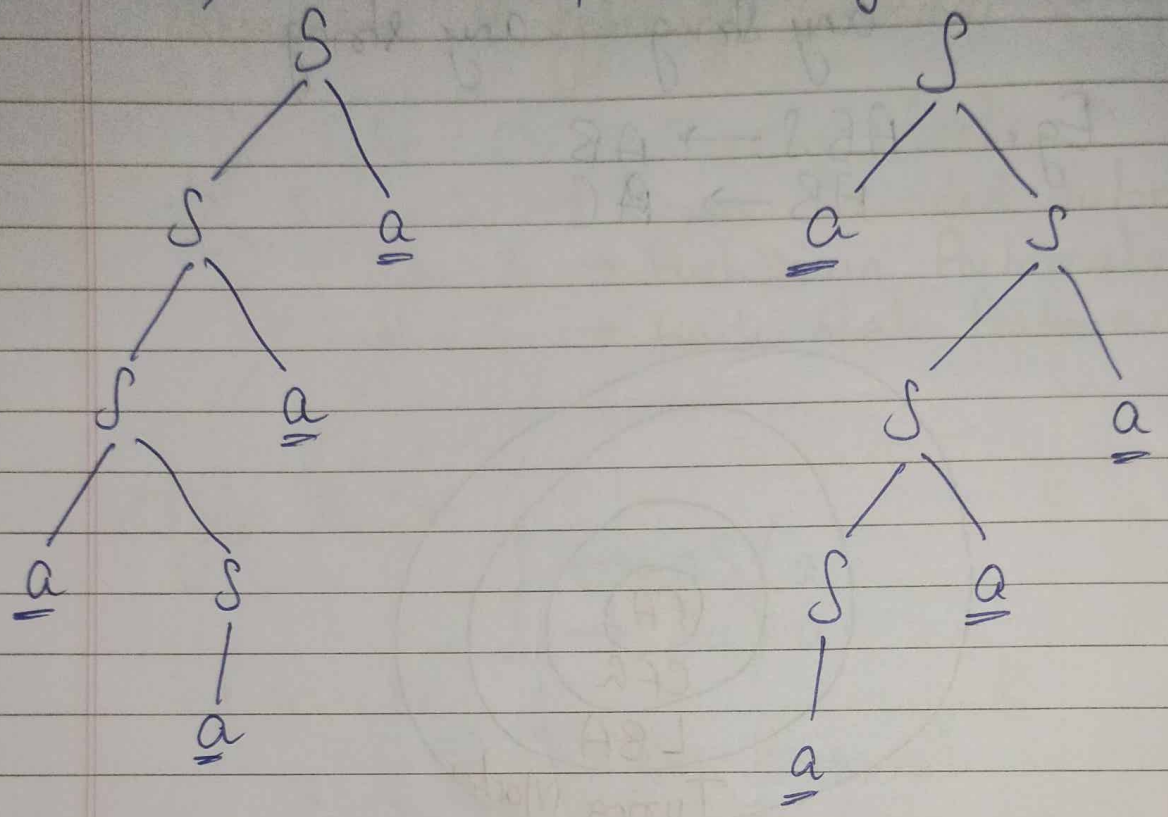
A grammar is said to be ambigous if for a given string generated by the grammar, there exist :

i) More than 1 parse Tree,
ii) Left most derivation &
iii) Right most derivation.

Parse Tree :- The process of deriving a string is called derivation. The geometrical representation of a derivation is called parse tree or derivation tree.

Q. $S \to aS \mid Sa \mid a$ check ambiguity.

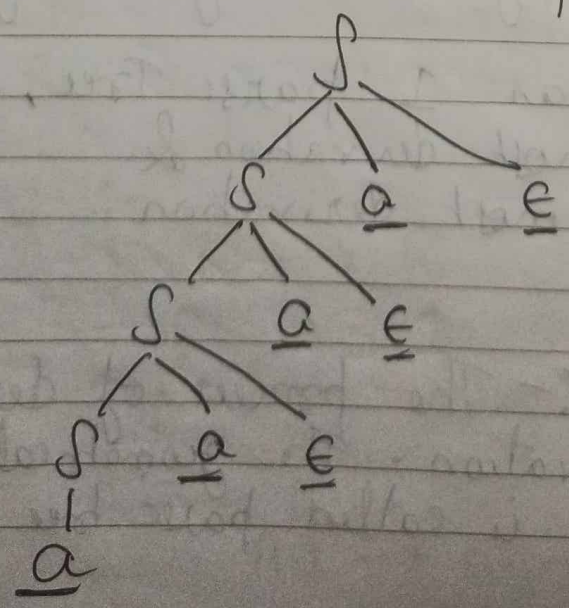
$\Rightarrow$ Let draw parse tree for aaaa.



Since we can draw more than 1 parse tree so, the ~~pro~~ Grammar is ambigous.

Leaf of parse tree gives us the string we are generating.

* ϵ can also be part of leaf.



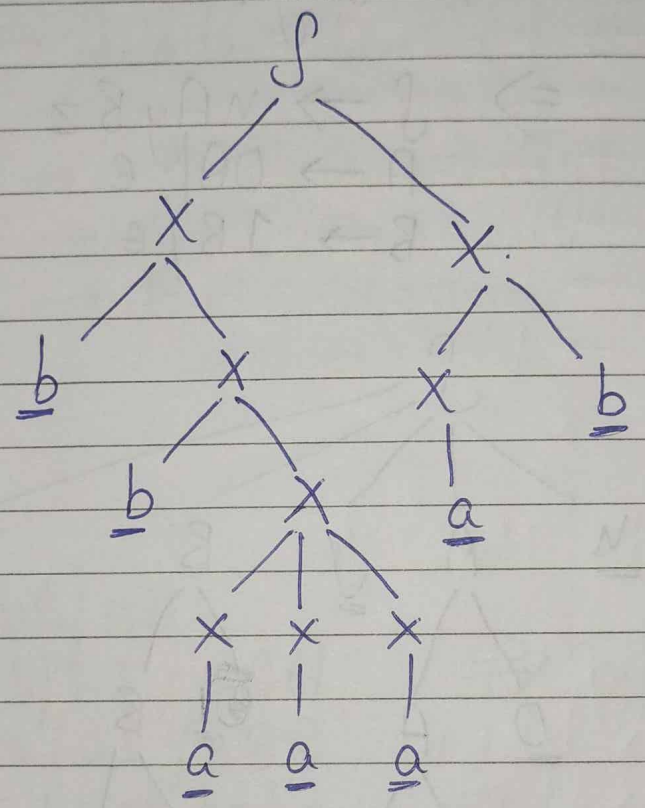
$\Rightarrow a a \epsilon a \epsilon a \epsilon$

$\Rightarrow$ aaaa

Q $S \to XX$
$X \to XXX / bX / Xb / a$

yild bbaaaab.

Sol →



⇒ bbaaaab.

Left Most Derivation & Rightmost Derivation

The process of deriving a string by expanding the leftmost non-terminal at each step is called as leftmost derivation.

The geometrical representation of leftmost derivation is called leftmost derivation tree.

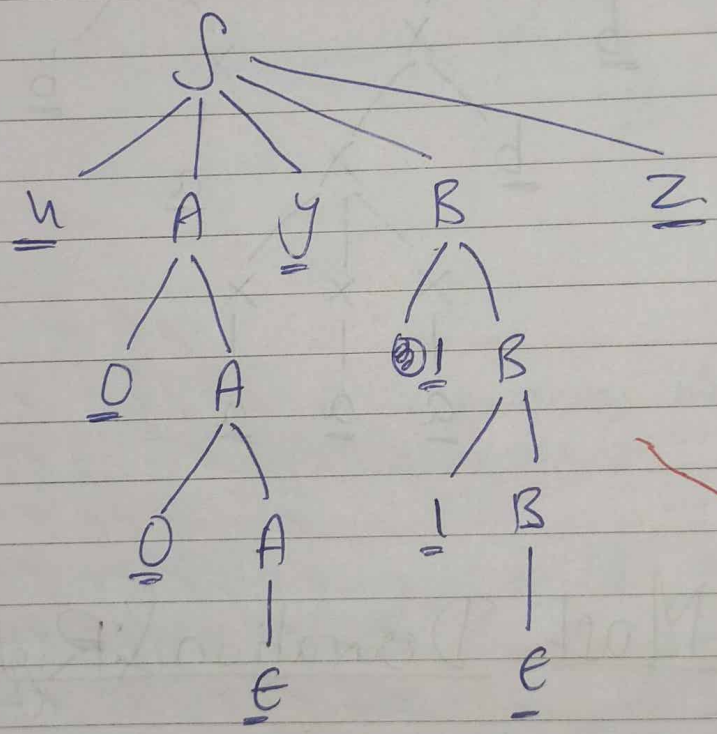
⇒ Rightmost terminal → Rightmost derivation

Q $L = \{ x 0^n y 1^n z \mid n \geq 0$
yeild $x00y11z$ using parse tree.

Sol →

$L = \{ x 0^n y 1^n z$

$\Rightarrow S \rightarrow xAyBz$
$A \rightarrow 0A \mid \epsilon$
$B \rightarrow 1B \mid \epsilon$

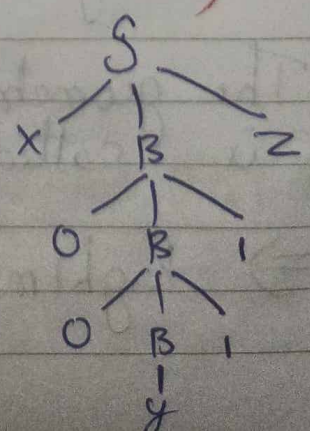


Both are correct

$\Rightarrow x00y11z.$

$\boxed{\text{or}}$

$S \rightarrow xBz$
$B \rightarrow y \mid 0B1$



Identify Type :-

Q.

$S \rightarrow AB$
$AS \rightarrow aB$
$B \rightarrow a$
$A \rightarrow b$

$\Rightarrow$ Type 0

Q

$S \rightarrow ACaB$
$aA \rightarrow Da$
$AC \rightarrow CB$
$AE \rightarrow E$
$EB \rightarrow E$

$\Rightarrow$ Type 0 ?

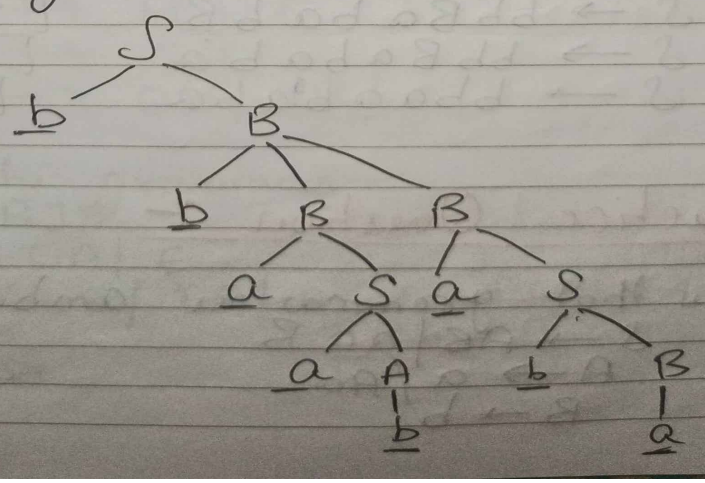
because $AE \rightarrow E$
$EB \rightarrow E$
have $2 > 1$
NT lyc > NT rgt

Q

$S \rightarrow bB / aA$
$A \rightarrow b / bS / aAA$
$B \rightarrow a / aS / bBB$
yeild bbaababa

$\Rightarrow$ Type 2.

Sol $\rightarrow$ 1) By Parse Tree :-



2) Left Most Derivation :-

$S \rightarrow bB$ $[\because B \rightarrow bBB]$

$S \rightarrow bbBB$ → We apply on Left one first

$S \rightarrow bbaSB$ $[\because B \rightarrow aS]$

$S \rightarrow bbaaAB$ $[\because S \rightarrow aA]$

$S \rightarrow bbaabSB$ $[\because A \rightarrow bS]$

$S \rightarrow bbaabaAB$ $[\because S \rightarrow aA]$

$S \rightarrow bbaababB$ $[\because A \rightarrow b]$

$S \rightarrow bbaababa$ $[\because B \rightarrow a]$.

3) Right Most Derivation :-

$S \rightarrow bB$

$S \rightarrow bbBB$ $[\because B \rightarrow bBB]$

$S \rightarrow bbBaS$ $[\because B \rightarrow aS]$

$S \rightarrow bbBabB$ $[\because S \rightarrow bB]$

$S \rightarrow bbBabaS$ $[\because B \rightarrow aS]$

$S \rightarrow bbBababB$ $[\because S \rightarrow bB]$

$S \rightarrow bbBababa$ $[\because B \rightarrow a]$

$S \rightarrow bbaababa$ $[\because B \rightarrow a]$.

Practice Question :-

1) Show that grammar is ambigous.

$S \rightarrow AB \mid aaB$

$A \rightarrow a \mid Aa$

$B \rightarrow b$

2) Find CFG $L: \{a^n b^{2n} c^m \mid n, m >= 0\}$

Sol →

$S \rightarrow ABC$
$A \rightarrow aA \mid \epsilon$
$B \rightarrow bbB \mid \epsilon$
$C \rightarrow cC \mid \epsilon$

~~$S \rightarrow AB$~~
~~$A \rightarrow aABB \mid \epsilon$~~
~~$B \rightarrow cB \mid \epsilon$~~

3) Find CFG (i) Exactly one a.
(ii) Atleast one a.

Sol → (i)

$S \rightarrow AaA$
$A \rightarrow bA \mid \epsilon$

→ $\{b^* a b^*\}$

(ii)

$S \rightarrow AaA$
$A \rightarrow aA \mid bA \mid \epsilon$

→ $\{(a+b)^* a (a+b)^*\}$

4) CFG for R.E $r = 0^* 1 (0+1)^*$.

Sol →

$S \rightarrow A1B$
$A \rightarrow 0A \mid \epsilon$
$B \rightarrow 0B \mid 1B \mid \epsilon$

5) Consider the grammar.

$S \rightarrow A1B$
$A \rightarrow 0A \mid \epsilon$
$B \rightarrow 0B \mid 1B \mid \epsilon$

(i) LMD
(ii) RMD

Sol → (i) LMD :-

$S \rightarrow A1B$
$S \rightarrow 01B$
$S \rightarrow 011B$
$S \rightarrow 0110$

(ii) RMD :-

$S \rightarrow A1B$
$S \rightarrow A11B$
$S \rightarrow A110$
$S \rightarrow 0110$

Elimination of useless Symbol :-

Eg. $S \rightarrow aAB$
$A \rightarrow a/b$

Here B is useless symbol.

Q Eliminate useless symbol from given grammar

$S \rightarrow AB/a$
$A \rightarrow b$

Sol → Step 1 → Identify useless symbol

Here B is useless symbol.

Since B is useless ~~an~~ so, we remove entire of $S \to AB$.

$$S \to a$$
$$A \to b.$$

Now, since S does not have any non terminal A. So we can remove A too.

$$\Rightarrow \quad S \to a$$

Ans

Q. $S \to aB \mid bX$
$A \to BAd \mid bSX \mid a$
$B \to aSB \mid bBX$
$X \to SBD \mid aBX \mid ad$

Sol → Since S does not have any non-terminal A in it. So, we can remove it.

$$S \to aB \mid bX$$
$$B \to aSB \mid bBX$$
$$X \to SBD \mid aBX \mid ad$$

Now, since B will not generate any string as it is recursive grammar and B will come again and again with B. So, we can remove it.

$S \to aB \mid bX$
$X \to SBD \mid aBX \mid ad$

Now, since B is removed, so, we can remove $S \to aB$ from that start S.

$S \to bX$
$X \to SBD \mid aBX \mid ad$

Now, D is useless in X so, we can remove $X \to SBD$. and also, we can remove $X \to aBX$ as it contain B which is already removed.

$\Rightarrow$ $S \to bX$
$X \to ad$

Ans

Q. $A \to xyz \mid Xyzz$
$X \to xz \mid zYZ$
$Y \to yYy \mid Xz$
$Z \to Zy \mid Z$

Sol $\to$ Since A does not have Y in it so, we can remove entire rule of Y.

$A \to xyz \mid XyZZ$
$X \to xZ \mid zYZ$
$Z \to Zy \mid Z$

Now, we can remove Z too because it will not generate any final string as it will be a recursive grammar.

$A \to xyz \mid XyZZ$
$X \to xZ \mid zYZ$

Now, we can remove, $X \to zYZ$ too as there is no production rule for YZ.

$A \to xyz \mid XyZZ$
$X \to xZ$

Ans

~~Now, we can remove $A \to XyZZ$ as Z does not have production rule.~~

~~$A \to xyz$~~
~~$X \to xZ$~~

Q $S \to aC \mid SB$
$A \to bSCa$
$B \to aSB \mid bBC$
$C \to aBC \mid ad$

Sol → $S \to aC \mid SB$
$B \to aSB \mid bBC$
$C \to aBC \mid ad$

$\Rightarrow$ $S \to aC \mid SB$
$C \to aBC \mid ad$

$\Rightarrow$ $S \to aC$
$C \to ad$

Ans

Elimination of Unit Production :-

$S \to aA \mid aSB \mid a \mid A \mid AB$

$S \to A$
$S \to B$
$S \to C$
$S \to X$

→ Unit production. Exactly one Non-terminal in both side. No terminal is allowed.

Q

$S \to AB$
$A \to a$
$B \to C \mid b$
$C \to D$
$D \to E$
$E \to a$

Sol → Step 1 :- Identify unit production

1. $B \to C$
2. $C \to D$
3. $D \to E$

Step 2 :- Remove these production rule of unit production

$S \to AB$
$A \to a$
$B \to b$
$E \to a$

Now, since E is useless so, we can remove it

$S \to AB$
$A \to a$
$B \to b$

Now, since $B \to C$ & $C \to D$ & $D \to E$ & $E \to a$
So, $B \to a$ will also be there.
So, add this production rule.

$\Rightarrow$ $S \to AB$
$A \to a$
$B \to b / a$

Ans

Q. $S \to A / bb$
$A \to B / b$
$B \to S / a$

Sol $\to$ Step 1 $\to$ Identify unit production

$S \to A$
$A \to B$
$B \to S$

Step 2 :- Remove those unit production.

and since $S \to A$ & $A \to b$ So.

$\Rightarrow S \to b$

also. $S \to A$ & $A \to B$ & $B \to a$

$\Rightarrow S \to a$

So, we add $S \to a$ & $S \to b$ in S.

$S \to bb / a / b$

~~$A \to b$~~

~~$B \to a$~~

A & B are removed because it is ~~useful~~ useless and not relevant for S.

Elimination of NULL production :-

$S \to \epsilon$

$A \to \epsilon$

Q $S \to aA$

$A \to b / \epsilon$

Sol → Step 1 → Identify NULL production

$A \to \epsilon$

Remove $A \to \epsilon$ and make arrangement in S by putting $A \to \epsilon$.

$S \to a / aA$

$A \to b$

Ans

Q $S \to ABAC$
$A \to aA \mid \epsilon$
$B \to bB \mid \epsilon$
$C \to c$

Sol → Step 1 → Identify null production

$A \to \epsilon$
$B \to \epsilon$

Remove $A \to \epsilon$ and $B \to \epsilon$
for $S \to ABAC$
If we put ϵ in first A
$S \to BAC$
If we put ϵ in second A
$S \to ABC$
If we put ϵ in B
$S \to AAC$
If we put ϵ in A & B.
$S \to AC$
If we put ϵ in A & A
$S \to BC$
If we put ϵ in ABA
$S \to C$
If we put ϵ in $A \to aA$, $A \to a$ & If we put it in $B \to bB$, $B \to \epsilon$

$S \to ABAC \mid BAC \mid ABC \mid AAC \mid AC \mid BC \mid C$
$A \to aA \mid a$
$B \to bB \mid b$
$C \to c$

Q. $S \to aSa$
$S \to bSb \mid \epsilon$

Sol $\to$ $S \to aSa \mid aa$
$S \to bSb \mid bb$

CNF (Chomsky Normal Form) :-

A grammar where every production is either of the form $A \to BC$ or $A \to c$.

$S \to a$ ✓
$S \to aA$ ✗
$S \to A$ ✗
$S \to aAb$ ✗
$S \to XY$ ✓

Q $S \to aA$
$A \to bA$ Convert it in CNF.

Sol $\to$ $S \to aA$
$A \to bA$

Let assume $C_a \to a$

So, $S \to C_a A$
$A \to bA$
$C_a \to a$

Now lets assume $C_b \to b$

So, $S \to C_a A$
$A \to C_b A$
$C_a \to a$, $C_b \to b$

Now, since Both $S \to C_a A$
$A \to C_b A$ are in form $A \to BC$ so there is no need to further simplify it.

$\Rightarrow$ $S \to C_a A$
$A \to C_b A$
$C_a \to a$
$C_b \to b$

Ans

Q. $S \to bA / aB$
$A \to bAA / aS / a$
$B \to aBB / bS / a$

Sol $\to$ $S \to bA / aB$
$A \to bAA / aS / a$
$B \to aBB / bS / a$

Lets assume $C_a \to a$
$C_b \to b$.

$\Rightarrow$
$S \to C_b A / C_a B$
$A \to C_b AA / C_a S / a$
$B \to C_a BB / C_b S / a$

Now, S already reduced in CNF. So, for A,
Now, lets assume AA be D.

$$D \rightarrow AA$$

$$\Rightarrow \begin{aligned} S &\rightarrow C_b A \mid C_a B \\ A &\rightarrow C_a D \mid C_a S \mid a \\ B &\rightarrow C_a BB \mid C_b S \mid a \end{aligned}$$

Now, only $B \rightarrow C_a BB$ remain in non-CNF
So, lets assume $BB \rightarrow E$.

$$\Rightarrow \begin{aligned} S &\rightarrow C_b A \mid C_a B \\ A &\rightarrow C_a D \mid C_a S \mid a \\ B &\rightarrow C_b E \mid C_b S \mid a \\ C_a &\rightarrow a \\ C_b &\rightarrow b \\ D &\rightarrow AA \\ E &\rightarrow BB \end{aligned}$$

Ans

Q. $S \rightarrow 1A \mid 0B$
$A \rightarrow 1AA \mid 0S \mid 0$
$B \rightarrow 0BB \mid 1$

Sol $\rightarrow$ $S \rightarrow 1A \mid 0B$
$A \rightarrow 1AA \mid 0S \mid 0$
$B \rightarrow 0BB \mid 1$

assume $C_0 \rightarrow 0$
$C_1 \rightarrow 1$

$\Rightarrow S \to C_1 A \mid C_0 B$

$A \to C_1 AA \mid C_0 S \mid 0$

$B \to C_0 BB \mid 1$

Assume AA as D.

BB as E

$\Rightarrow$

$S \to C_1 A \mid C_0 B$

$A \to C_1 D \mid C_0 S \mid 0$

$B \to C_0 E \mid 1$

$C_0 \to 0$

$C_1 \to 1$

$D \to AA$

$E \to BB$

Ans

Q. $S \to abSb \mid a \mid aAb$

$A \to bS \mid aAAb$.

Sol $\to$ Assume $C_a \to a$

$C_b \to b$.

$S \to C_a C_b S C_b \mid C_a \mid C_a A C_b$

$A \to C_b S \mid C_a A A C_b$.

Assume $D \to A C_b$.

$S \to C_a C_b S C_b \mid a \mid C_a D$

$A \to C_b S \mid C_a A D$

Assume $E \to C_a C_b$ and $F \to C_a A$

$S \to ESC_b \mid a \mid C_a D$
$A \to C_b S \mid FD$

Assume $G \to SC_b$

$S \to EG \mid a \mid C_a D$
$A \to C_b S \mid FD$
$C_a \to a$
$C_b \to b$
$D \to AC_b$
$E \to C_a C_b$
$F \to C_a A$
$G \to SC_b$ Ans

GNF (Greibach Normal Form) :-

A CFG is said to be in ~~GF~~ GNF if every production is of the form $A \to a\alpha$ where $\alpha \to$ any no. of non-terminal.

$S \to a$ ✓
$S \to aAB$ ✓
$S \to AaB$ ✗
$S \to aAaB$ ✗

Q $S \to AB \mid BC$
$A \to aB \mid bA \mid a$
$B \to bB \mid cC \mid b$
$C \to c$

Sol → $S \to AB \mid BC$ --- (i)
$A \to aB \mid bA \mid a$ --- (ii)
$B \to bB \mid cC \mid b$ --- (iii)
$C \to c$

In this Put $A \to aB \mid bA \mid a$ in S

$S \to aBB \mid bAB \mid aB \mid BC$ --- (iv)

In this Put $B \to bB \mid cC \mid b$

$S \to aBB \mid bAB \mid aB \mid bBC \mid cCC \mid bC$
$A \to aB \mid bA \mid a$
$B \to bB \mid cC \mid b$
$C \to c$

Ans

Q. $S \to abaSa \mid aba$

Sol → $S \to abaSa \mid aba$

Let $A \to ba$
Put it in S.
$S \to aASa \mid aA$
Let $B \to a$
$S \to aASB \mid aA$
$A \to bB$

$\Rightarrow$ $S \rightarrow aASB / aA$
$A \rightarrow bB$
$B \rightarrow a$

Ans

Q. $S \rightarrow AB$
$A \rightarrow aA / bB / b$
$B \rightarrow b$

Sol $\rightarrow$ Putting value of A in S.

$S \rightarrow aABB / bBB / bB$
$A \rightarrow aA / bB / b$
$B \rightarrow b$

Ans

Recursive Grammar :- If non-terminal Symbol of left side is also there in right side.

$S \rightarrow SA$ (RG)
$S \rightarrow AB$ (NRG)
$S \rightarrow SaB$ (RG)
$S \rightarrow aAB$ (NRG)
$S \rightarrow a$ (NRG)
$S \rightarrow aA$ (NRG)

Q $S \to AB$ $\Rightarrow$ CNF to GNF
$S \to BS \mid a$
$B \to SA \mid b$

Sol →
Assume $S \to A_1$, $A \to A_2$, $B \to A_3$

Step 1 →

$A_1 \to A_2 A_3$ $\quad 1 > 2$ (false)
$A_2 \to A_3 A_1 \mid a$ $\quad 2 > 3$ (false)
$A_3 \to A_1 A_2 \mid b$ $\quad 3 > 1$ (True)

It is true for $A_3 \to A_1 A_2 \mid b$ so we will reduce it further.

Step 2:-
$A_3 \to A_1 A_2$

$A_3 \to A_2 A_3 A_2$ $\quad (3 > 2)$ (True)

It is still true so will continue reducing

$A_3 \to A_3 A_1 A_3 A_2$ $\quad (3 > 3)$ false

Step 3:- We will now introduce new variable.

$A_3 \to A_1 A_2$
$A_3 \to A_2 A_3 A_2$
$A_3 \to a A_3 A_2$

$\Rightarrow A_3 \to a A_3 A_2 \mid b \mid A_3 A_1 A_3 A_2$
$A_3 \to a A_3 A_2 B \mid bB \mid a A_3 A_2 \mid b$
$B \to A_1 A_3 A_2 B \mid A_1 A_3 A_2$

So, Now, A_3 will be in GNF form

Putting value of A_3 in A_2

$A_2 \rightarrow A_3 A_1 / a$

$\Rightarrow A_2 \rightarrow aA_3A_2BA_1 / bBA_1 / aA_3A_2A_1 / bA_1 / a$

Putting value of A_2 in A_1

$A_1 \rightarrow A_2 A_3$

$A_1 \rightarrow aA_3A_2BA_1A_3 / bBA_1A_3 / aA_3A_2A_1A_3 / bA_1A_3 / aA_3$

Putting the value of A_1 in B we get

$B \rightarrow aA_3A_2BA_1A_3A_3A_2B / bBA_1A_3A_3A_2B /$
$aA_3A_2A_1A_3A_3A_2B / bA_1A_3A_3A_2B / aA_3A_3A_2B /$
$aA_3A_2BA_1A_3A_3A_2 / bBA_1A_3A_3A_2 / aA_3A_2A_1A_3A_3A_2 /$
$bA_1A_3A_3A_2 / aA_3A_3A_2$

$A_1 \rightarrow aA_3A_2BA_1A_3 / bBA_1A_3 / aA_3A_2A_1A_3 / bA_1A_3 / aA_3$

$A_2 \rightarrow aA_3A_2BA_1 / bBA_1 / aA_3A_2A_1 / bA_1 / a$

$A_3 \rightarrow aA_3A_2B / bB / aA_3A_2 / b$

Ans

RG	CFG	CNF	GNF
✗ $S \to AB$	✓ $S \to AB$	$S \to AB$	$S \to a / aA / aAB$
✓ $S \to aAB$	✓ $S \to aAB$	$S \to a$	
✗ $S \to AaB$	✓ $S \to AaB$	$A \to a$	
✓ $S \to a$	✓ $S \to a$	$B \to b$	
✗ $S \to aSBb$	✓ $S \to aSBb$		

$S \to aV/a \longrightarrow$ GNF

$Va/a \longrightarrow$ Not in GNF

CFG TO FA :-

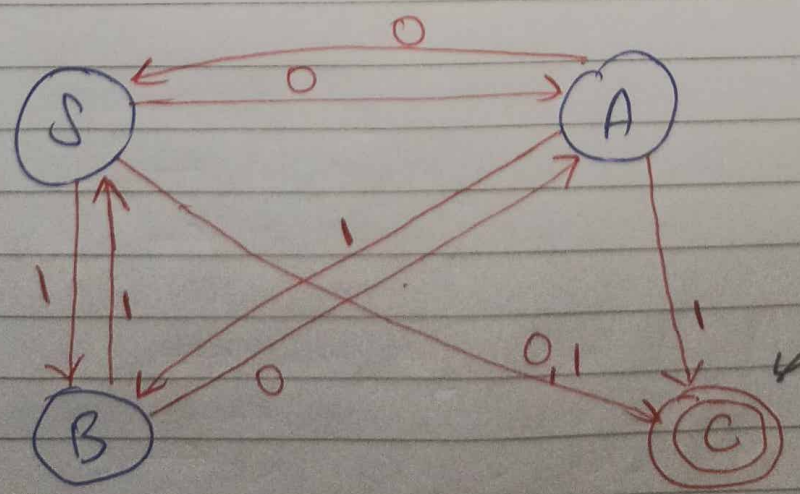
Q

$S \to 0A / 1B / 0 / 1$

$A \to 0S / 1B / 1$

$B \to 0A / 1S$

Sol $\to$ $V_N \to S, A, B$ $\qquad$ $V_T \to 0, 1$

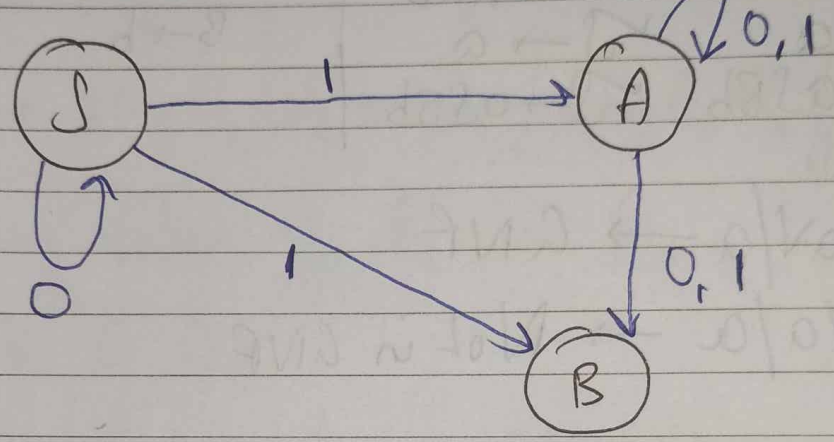


new state for terminal 0,1. it will be final too

Q $S \to 0S \mid 1A \mid 1$

$A \to 0A \mid 1A \mid 0 \mid 1$

Sol $\to$ $V_N \to S, A.$ $V_T \to 0, 1$



Ans