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CS303 Tutorial 5

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Answers

1(a) Grammar given : $S \rightarrow BSB \mid B \mid \epsilon$
$B \rightarrow 00 \mid \epsilon$

Step 1: Start symbol S, appears on RHS. Add production $S' \rightarrow S$

$S' \rightarrow S$
$S \rightarrow BSB \mid B \mid \epsilon$ Now, S' is start symbol
$B \rightarrow 00 \mid \epsilon$

Step 2: Remove Null productions

remove $B \rightarrow \epsilon$ $\Rightarrow$
$$\begin{cases} S' \rightarrow S \\ S \rightarrow BSB \mid BS \mid SB \mid S \mid B \mid \epsilon \\ B \rightarrow 00 \end{cases}$$

remove $S \rightarrow \epsilon$ $\Rightarrow$
$$\begin{cases} S' \rightarrow S \mid \epsilon \\ S \rightarrow BSB \mid BS \mid SB \mid S \mid B \mid BB \\ B \rightarrow 00 \end{cases}$$

$S' \rightarrow \epsilon$ is not removed because S' is start symbol, this is valid production in CNF

Step 3: Remove all unit productions

remove $S \to S$ $\Rightarrow$
$$\begin{cases} S' \to S \mid \epsilon \\ S \to BSB \mid BS \mid SB \mid B \mid BB \\ B \to 00 \end{cases}$$

remove $S \to B$ $\Rightarrow$
$$\begin{cases} S' \to S \mid \epsilon \\ S \to BSB \mid BS \mid SB \mid 00 \mid BB \\ B \to 00 \end{cases}$$

remove $S' \to S$ $\Rightarrow$
$$\begin{cases} S' \to BSB \mid BS \mid SB \mid 00 \mid BB \mid \epsilon \\ S \to BSB \mid BS \mid SB \mid 00 \mid BB \\ B \to 00 \end{cases}$$

Step 4: Convert productions with more than 2 non-terminals on RHS to valid forms by adding productions

$S' \to BV_1 \mid BS \mid SB \mid 00 \mid BB \mid \epsilon$

$S \to BV_1 \mid BS \mid SB \mid 00 \mid BB$

$V_1 \to SB$

$B \to 00$

Step 5: Convert productions with more than one terminal on RHS to valid forms by adding productions

$S' \to BV_1 \mid BS \mid SB \mid 00 \mid BB \mid \epsilon$

$S \to BV_1 \mid BS \mid SB \mid 00 \mid BB$

$V_1 \to SB$

$B \to T_1 T_1$

$T_1 \to 0$

$\therefore$ CNF of given grammar is

$$\boxed{\begin{array}{l} S' \rightarrow BV_1 \mid BS \mid SB \mid 00 \mid BB \mid \epsilon \\ S \rightarrow BV_1 \mid BS \mid SB \mid BB \mid 00 \\ V_1 \rightarrow SB \\ B \rightarrow T_1T_1 \\ T_1 \rightarrow 0 \end{array}}$$

1(b) Given grammar,

$$\begin{array}{l} S \rightarrow S1 \mid S2 \\ S1 \rightarrow S_1b \mid Ab \mid \lambda \\ A \rightarrow aAb \mid ab \\ S_2 \rightarrow S_2a \mid Ba \mid \lambda \\ B \rightarrow bBa \mid ba \end{array}$$

Step 1: Remove null production

Remove $S_1 \rightarrow \lambda$ $\Rightarrow$
$$\left\{ \begin{array}{l} S_1 \rightarrow S_1 \mid S_2 \mid \lambda \\ S_1 \rightarrow S_1b \mid b \mid Ab \\ A \rightarrow aAb \mid ab \\ S_2 \rightarrow S_2a \mid Ba \mid \lambda \\ B \rightarrow bBa \mid ba \end{array} \right.$$

Remove $S_2 \rightarrow \lambda$ $\Rightarrow$
$$\left\{ \begin{array}{l} S \rightarrow S_1 \mid S_2 \mid \lambda \\ S_1 \rightarrow S_1b \mid b \mid Ab \\ A \rightarrow aAb \mid ab \\ S_2 \rightarrow S_2a \mid a \mid Ba \\ B \rightarrow bBa \mid ba \end{array} \right.$$

$S \to \lambda$ is not removed because S is start symbol and production is valid under CNF.

Step 2: Remove all unit productions

Remove $S \to S_1$ $\Rightarrow$

$$\begin{cases} S \to S_1 b \mid b \mid Ab \mid S_2 \mid \lambda \\ S_1 \to S_1 b \mid b \mid Ab \\ A \to aAb \mid ab \\ S_2 \to S_2 a \mid a \mid Ba \\ B \to bBa \mid ba \end{cases}$$

Remove $S \to S_2$ $\Rightarrow$

$$\begin{cases} S \to S_1 b \mid b \mid Ab \mid S_2 a \mid a \mid Ba \mid \lambda \\ S_1 \to S_1 b \mid b \mid Ab \\ A \to aAb \mid ab \\ S_2 \to S_2 a \mid a \mid Ba \\ B \to bBa \mid ba \end{cases}$$

Step 3: Add relevant productions for terminals

$$\boxed{\begin{array}{ll} S \to S_1 T_b \mid b \mid A T_b \mid S_2 T_a \mid a \mid B T_a \mid \lambda & \\ S_1 \to S_1 T_b \mid b \mid A T_b & \\ A \to T_a V_1 \mid T_a T_b & T_a \to a \\ V_1 \to A T_b & T_b \to b \\ S_2 \to S_2 T_a \mid a \mid B T_a & \\ B \to T_b V_2 \mid T_b T_a & \\ V_2 \to V_b T_a & \end{array}}$$

2. Given grammar, $S \rightarrow XA \mid BB$
$B \rightarrow b \mid SB$
$X \rightarrow b$
$A \rightarrow a$

$S \rightarrow XA$ is invalid production. Substitute $X \rightarrow b$

$S \rightarrow bA \mid BB$
$B \rightarrow b \mid SB$
$X \rightarrow b$
$A \rightarrow a$

Substitute $S \rightarrow bA \mid BB$ in $B \rightarrow b \mid SB$ to make it valid.

$S \rightarrow bA \mid BB$
$B \rightarrow b \mid bAB \mid BBB$
$X \rightarrow b$
$A \rightarrow a$

$B \rightarrow BBB$ is invalid production. Replace it as shown

$S \rightarrow bA \mid BB$
$$\left.\begin{array}{l} B \rightarrow bC \mid bABC \\ C \rightarrow BBC \mid \epsilon \end{array}\right\}$$
$A \rightarrow a$

Remove null production $C \rightarrow \epsilon$

$S \rightarrow bA \mid BB$
$B \rightarrow bC \mid b \mid bABC \mid bAB$
$C \rightarrow BBC \mid BB$
$A \rightarrow a$

C → BBC | BB are invalid under GNF. Substitute B → bC | b | bABC | bAB for making them valid

S → bA | BB

B → bC | b | bABC | bAB

C → bCBC | bBC | bABCBC | bABBC | bCB | bB | bABCB | bABB

A → a

Substitute B → bC | b | bABC | bAB in S → BB

$$\boxed{\begin{array}{l} S \to bA \mid bCB \mid bB \mid bABCB \mid bABB \\ B \to bC \mid b \mid bABC \mid bAB \\ C \to bCBC \mid bBC \mid bABCBC \mid bABBC \mid bCB \mid bB \mid bABCB \mid bABB \\ A \to a \end{array}}$$

3. Given grammar is $S \to ABC \mid BC$

$A \to aA \mid a$

$B \to b \mid C$

$C \to cc \mid dd \mid \epsilon$

Clearly

(1) C is nullable because of the production $C \to \epsilon$

(2) B is nullable due to the following productions.

$B \to C$ and $C \to \epsilon$

$$B \xRightarrow{B \to C} C \xRightarrow{C \to \epsilon} \epsilon$$

(3) A is not nullable because there is no derivation to prove A is nullable

$$A \xRightarrow{A \to aA} aA \Rightarrow aaA \Rightarrow aaaA \Rightarrow \ldots$$

(4) S is nullable because of the following productions.

$S \to BC,\ B \to C,\ C \to \epsilon$

$$S \xRightarrow{S \to BC} BC \xRightarrow{B \to C} CC \xRightarrow{C \to \epsilon} \epsilon C \xRightarrow{C \to \epsilon} \epsilon$$