Introduction to Theoretical Computer Science

Exercise tasks

Preparation for mid-term exam – part 2

Faculty of Electrical Engineering and Computing
University of Zagreb

Task 12

- Construct grammar over the alphabet {0,1,2} that generates sequences in which there are no consecutive repetitions of the sub-sequence "01".

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  - We simulate the work of automata which accepts all sequences in which there are no consecutive subsequences '01'.

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G=(V,T,P,S)
V={S,A,B,C}, T={0,1,2}

Task 12

- Construct grammar over the alphabet {0,1,2} that generates sequences in which there are no consecutive repetitions of the sub-sequence "01".

- We simulate the work of automata which accepts all sequences in which there are no consecutive subsequences '01'.

G=(V,T,P,S)
V={S,A,B,C}, T={0,1,2}

$S \rightarrow 0A \mid 1S \mid 2S \mid \varepsilon$

- A marks that “0” has been generated

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V={S,A,B,C}, T={0,1,2}

$S \rightarrow 0A \mid 1S \mid 2S \mid \varepsilon$
$A \rightarrow 0A \mid 1B \mid 2S \mid \varepsilon$

- A marks that “0” has been generated
- B marks that “01” has been generated

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  - We simulate the work of automata which accepts all sequences in which there are no consecutive subsequences '01'.

$G=(V,T,P,S)$
$V=\{S,A,B,C\}$, $T=\{0,1,2\}$

$S \rightarrow 0A \mid 1S \mid 2S \mid \varepsilon$
$A \rightarrow 0A \mid 1B \mid 2S \mid \varepsilon$
$B \rightarrow 0C \mid 1S \mid 2S \mid \varepsilon$

- A marks that “0” has been generated
- B marks that “01” has been generated
- C marks that “010” has been generated

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- We simulate the work of automata which accepts all sequences in which there are no consecutive subsequences '01'.

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$S \rightarrow 0A \mid 1S \mid 2S \mid \varepsilon$
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$C \rightarrow 0A \mid 2S \mid \varepsilon$

- A marks that “0” has been generated
- B marks that “01” has been generated
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Task 13

- Using the given DFA construct the grammar which generates sequences is accepted by it.

	a	b	c	
q_0	q_0	q_1	q_2	1
q_1	q_2	q_0	q_1	0
q_2	q_1	q_2	q_0	0

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DFA $M = (Q, \Sigma, \delta, q_0, F)$

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- V = Q, V ⇒ q_0□S,q_1□A,q_2□B
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S $\rightarrow$

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$S \rightarrow$

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$S \rightarrow aS$

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DFA $M = (Q, \Sigma, \delta, q_0, F)$

***G* = (*V*, *T*, *P*, *S*)**

- V = Q, V $\Rightarrow$ q_0□S,q_1□A,q_2□B
- T = □, S = q_0
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S $\rightarrow$ aS | bA

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$S \rightarrow aS \mid bA$

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$S \rightarrow aS \mid bA \mid cB$

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$S \rightarrow aS \mid bA \mid cB$

$A \rightarrow aB \mid bS \mid cA$

$B \rightarrow aA \mid bB \mid cS$

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- □(A,x) = B □ A□xB
- A□F □ A$\rightarrow\varepsilon$

$S \rightarrow aS \mid bA \mid cB$

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$S \rightarrow aS \mid bA \mid cB$

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$S \rightarrow aS \mid bA \mid cB \mid \varepsilon$

$A \rightarrow aB \mid bS \mid cA$

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- □(A,x) = B □ A□xB
- A□F □ A$\to\varepsilon$

$S \to aS \mid bA \mid cB \mid \varepsilon$

$A \to aB \mid bS \mid cA$

$B \to aA \mid bB \mid cS$

Task 14

- From the given left-linear grammar construct NFA.

$S \to Ac$	$A \to Bb$	$B \to A$
$S \to Aab$	$A \to cab$	$B \to ca$
$S \to Ba$	$A \to Sb$	$B \to Aaba$

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Algorithm:

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Algorithm:

1. Construct grammar $\boldsymbol{G_2}$ in which the right side of the productions are written in reverse order compared to those of the grammar $\boldsymbol{G_1}$

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Algorithm:

1. Construct grammar $\boldsymbol{G_2}$ in which the right side of the productions are written in reverse order compared to those of the grammar $\boldsymbol{G_1}$
2. From the grammar $\boldsymbol{G_2}$ construct grammar $\boldsymbol{G_3}$ in which all production rules are of type $A \to bC$ or $A \to \varepsilon$

Task 14

- From the given left-linear grammar construct NFA.

$S \to Ac$	$A \to Bb$	$B \to A$
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Algorithm:

1. Construct grammar G_2 in which the right side of the productions are written in reverse order compared to those of the grammar G_1
2. From the grammar G_2 construct grammar G_3 in which all production rules are of type $A \to bC$ or $A \to \varepsilon$
3. Construct NFA M_1 which accepts sequences generated by the grammar G_3

Task 14

- From the given left-linear grammar construct NFA.

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1. Construct grammar G_2 in which the right side of the productions are written in reverse order compared to those of the grammar G_1
2. From the grammar G_2 construct grammar G_3 in which all production rules are of type $A \to bC$ or $A \to \varepsilon$
3. Construct NFA M_1 which accepts sequences generated by the grammar G_3
4. Construct NFA M_2 which accepts sequences written in reverse order compared to those accepted by NFA M_1

Task 14

1. Construct grammar G_2 in which the right side of the productions are written in reverse order compared to those of the grammar G_1

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1. Construct grammar G_2 in which the right side of the productions are written in reverse order compared to those of the grammar G_1

$G_1 = (V, T, P_1, S)$

$S \rightarrow Ac$	$A \rightarrow Bb$	$B \rightarrow A$
$S \rightarrow Aab$	$A \rightarrow cab$	$B \rightarrow ca$
$S \rightarrow Ba$	$A \rightarrow Sb$	$B \rightarrow Aaba$

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1. Construct grammar G_2 in which the right side of the productions are written in reverse order compared to those of the grammar G_1

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$S \to Aab$	$A \to cab$	$B \to ca$
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$G_2 = (V, T, P_2, S)$

$S \to cA$	$A \to bB$	$B \to A$
$S \to baA$	$A \to bac$	$B \to ac$
$S \to aB$	$A \to bS$	$B \to abaA$

Task 14

2. From the grammar G_2 construct grammar G_3 in which all production rules are of type $A \rightarrow bC$ or $A \rightarrow \varepsilon$

$G_2 = (V_2, T, P_2, S)$

$S \rightarrow cA$	$A \rightarrow bB$	$B \rightarrow A$
$S \rightarrow baA$	$A \rightarrow bac$	$B \rightarrow ac$
$S \rightarrow aB$	$A \rightarrow bS$	$B \rightarrow abaA$

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2. From the grammar $\boldsymbol{G_2}$ construct grammar $\boldsymbol{G_3}$ in which all production rules are of type $A \to bC$ or $A \to \varepsilon$

$G_2 = (V_2, T, P_2, S)$

$S \to cA$	$A \to bB$	$B \to A$
$S \to baA$	$A \to bac$	$B \to ac$
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- If the right side of the production rule does not end with non-terminal symbol

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- If the right side of the production rule does not end with non-terminal symbol
  - Add [ε] to the end of the right side and add production rule $[\varepsilon] \rightarrow \varepsilon$

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2. From the grammar $\boldsymbol{G_2}$ construct grammar $\boldsymbol{G_3}$ in which all production rules are of type $A \rightarrow bC$ or $A \rightarrow \varepsilon$

$\boldsymbol{G_2 = (V_2, T, P_2, S)}$

$S \rightarrow cA$	$A \rightarrow bB$	$B \rightarrow A$
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- If the right side of the production rule does not end with non-terminal symbol
  - Add [ε] to the end of the right side and add production rule [ε] → ε
- Resolve unit productions

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- If the right side of the production rule does not end with non-terminal symbol
  - Add $[\varepsilon]$ to the end of the right side and add production rule $[\varepsilon] \to \varepsilon$
- Resolve unit productions
- Resolve right sides of the production rules with more than two symbols

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2. From the grammar $\boldsymbol{G_2}$ construct grammar $\boldsymbol{G_3}$ in which all production rules are of type $A \to bC$ or $A \to \varepsilon$

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$S \to cA$

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$G_2 = (V_2, T, P_2, S)$

$S \rightarrow cA$	$A \rightarrow bB$	$B \rightarrow A$
$S \rightarrow baA$	$A \rightarrow bac$	$B \rightarrow ac$
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$S \rightarrow cA$

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$G_3 = (V_3, T, P_3, S)$

$S \rightarrow cA$

$S \rightarrow b[aA]$

$[aA] \rightarrow aA$

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$G_2 = (V_2, T, P_2, S)$

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$S \rightarrow cA$

$S \rightarrow b[aA]$

$[aA] \rightarrow aA$

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- If the right side of the production rule does not end with non-terminal symbol
  - Add [ε] to the end of the right side and add production rule $[\varepsilon] \to \varepsilon$
- Resolve unit productions
- Resolve right sides of the production rules with more than two symbols

$G_3 = (V_3, T, P_3, S)$

$S \to cA$

$S \to b[aA]$

$[aA] \to aA$

$S \to aB$

Task 14

2. From the grammar $\boldsymbol{G_2}$ construct grammar $\boldsymbol{G_3}$ in which all production rules are of type $A \rightarrow bC$ or $A \rightarrow \varepsilon$

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$S \rightarrow cA$	$A \rightarrow bB$	$B \rightarrow A$
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$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$
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	$A \to bS$	$[baA] \to b[aA]$

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3. Construct NFA M_1 which accepts sequences generated by the grammar G_3

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$A \to b[ac\varepsilon]$
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$[c\varepsilon] \to c[\varepsilon]$
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$B \to bB$
$B \to b[ac\varepsilon]$
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NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$

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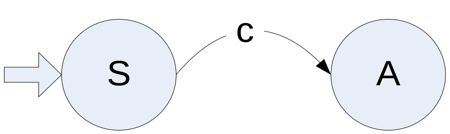

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$[c\varepsilon] \to c[\varepsilon]$

$A \to bS$

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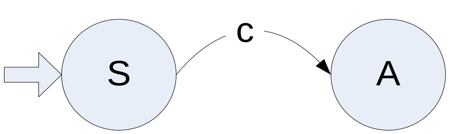

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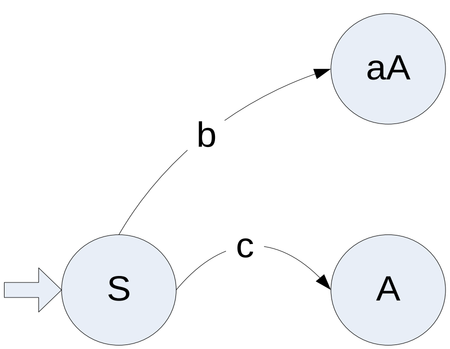

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$[aA] \rightarrow aA$ $\quad [ac\varepsilon] \rightarrow a[c\varepsilon]$ $\quad B \rightarrow bS$

$S \rightarrow aB$ $\quad [c\varepsilon] \rightarrow c[\varepsilon]$ $\quad B \rightarrow a[c\varepsilon]$

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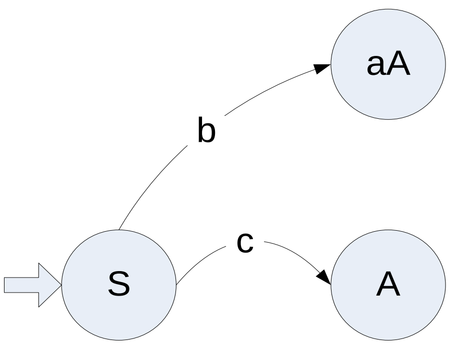

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- $Q=V$, $\Sigma=T$, $q_0=S$
- $A \rightarrow bC \Rightarrow \delta(A,b)=C$
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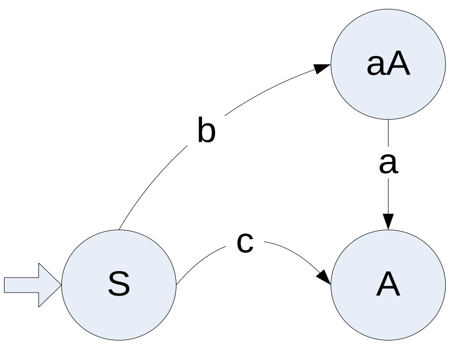
Task 14

3. Construct NFA $\boldsymbol{M_1}$ which accepts sequences generated by the grammar $\boldsymbol{G_3}$

$\boldsymbol{G_3 = (V_3, T, P_3, S)}$

$S \to cA$	$A \to bB$	$B \to bB$	$[\varepsilon] \to \varepsilon$
$S \to b[aA]$	$A \to b[ac\varepsilon]$	$B \to b[ac\varepsilon]$	
$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
		$B \to a[baA]$	
	$A \to bS$	$[baA] \to b[aA]$	



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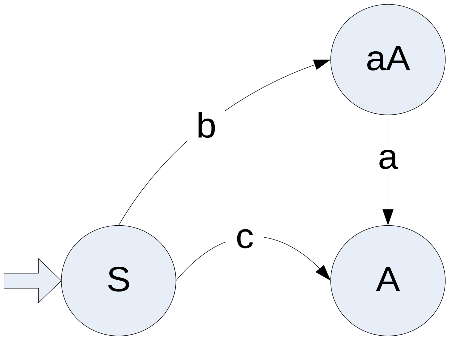
$S \to cA$	$A \to bB$	$B \to bB$	$[\varepsilon] \to \varepsilon$
$S \to b[aA]$	$A \to b[ac\varepsilon]$	$B \to b[ac\varepsilon]$	
$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
	$A \to bS$	$B \to a[baA]$	
		$[baA] \to b[aA]$	



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$[aA] \to aA$
$S \to aB$

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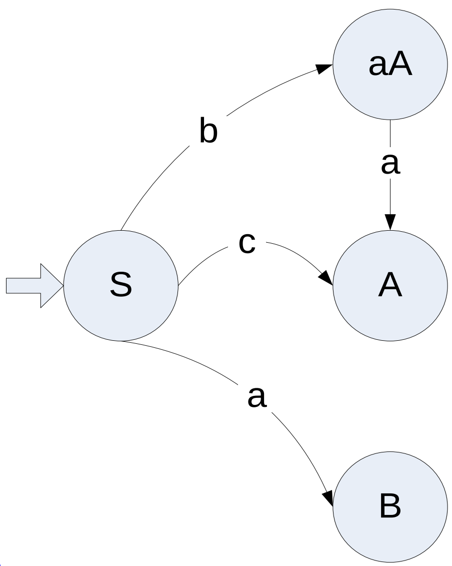
$A \to b[ac\varepsilon]$
$[ac\varepsilon] \to a[c\varepsilon]$
$[c\varepsilon] \to c[\varepsilon]$
$A \to bS$

$B \to bB$
$B \to b[ac\varepsilon]$
$B \to bS$
$B \to a[c\varepsilon]$
$B \to a[baA]$
$[baA] \to b[aA]$

$[\varepsilon] \to \varepsilon$



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$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
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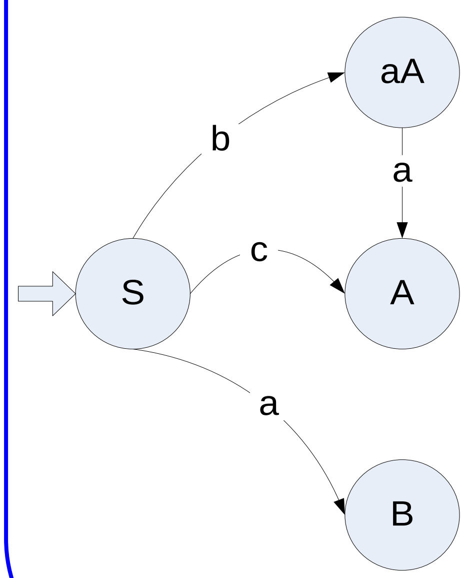
	$A \to bS$	$[baA] \to b[aA]$	



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$[ac\varepsilon] \to a[c\varepsilon]$
$[c\varepsilon] \to c[\varepsilon]$
$A \to bS$

$B \to bB$
$B \to b[ac\varepsilon]$
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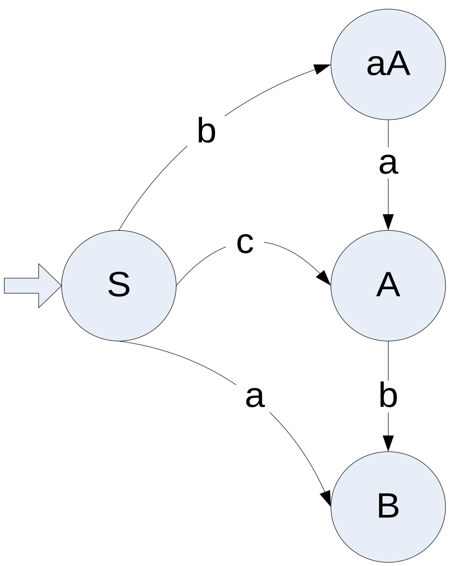
$[baA] \to b[aA]$

$[\varepsilon] \to \varepsilon$



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$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
	$A \to bS$	$B \to a[baA]$	
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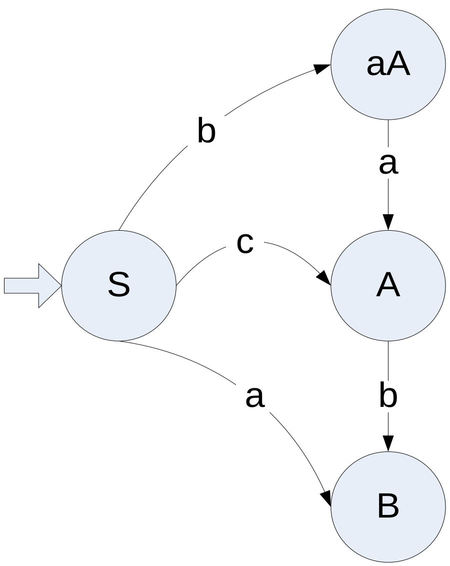

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$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
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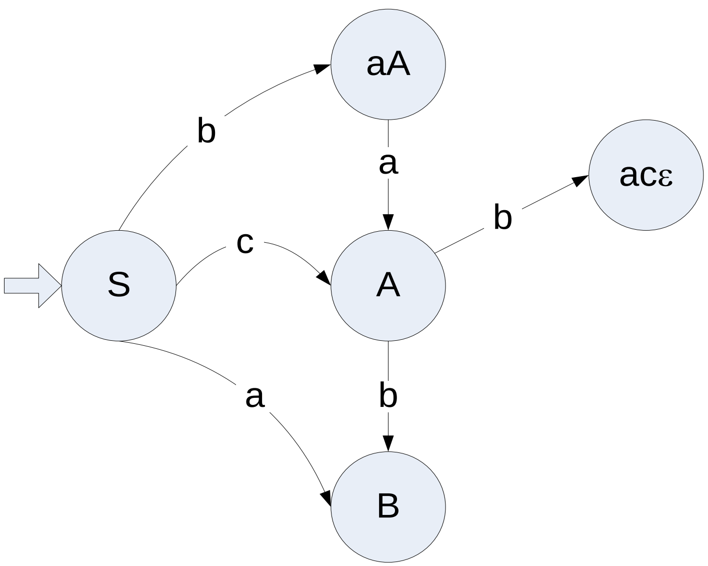

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$S \to b[aA]$

$[aA] \to aA$

$S \to aB$

$A \to bB$

$A \to b[ac\varepsilon]$

$[ac\varepsilon] \to a[c\varepsilon]$

$[c\varepsilon] \to c[\varepsilon]$

$A \to bS$

$B \to bB$

$B \to b[ac\varepsilon]$

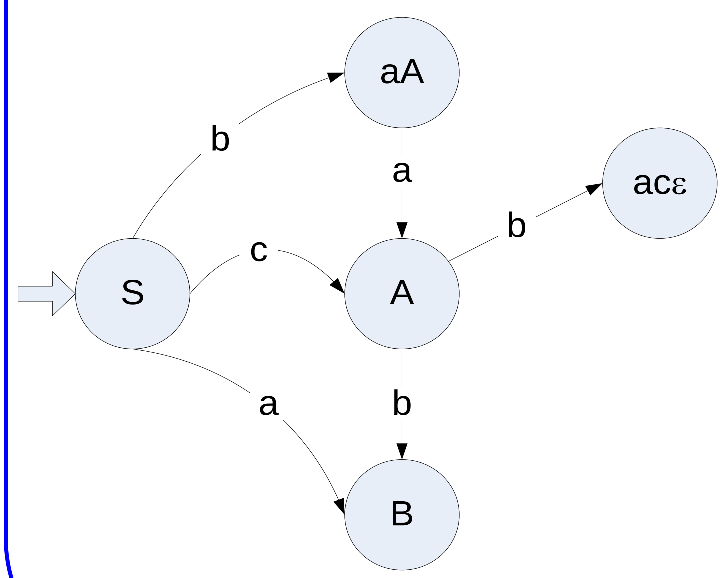
$B \to bS$

$B \to a[c\varepsilon]$

$B \to a[baA]$

$[baA] \to b[aA]$

$[\varepsilon] \to \varepsilon$



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$[aA] \to aA$
$S \to aB$

$A \to bB$
$A \to b[ac\varepsilon]$
$[ac\varepsilon] \to a[c\varepsilon]$
$[c\varepsilon] \to c[\varepsilon]$
$A \to bS$

$B \to bB$
$B \to b[ac\varepsilon]$
$B \to bS$
$B \to a[c\varepsilon]$
$B \to a[baA]$
$[baA] \to b[aA]$

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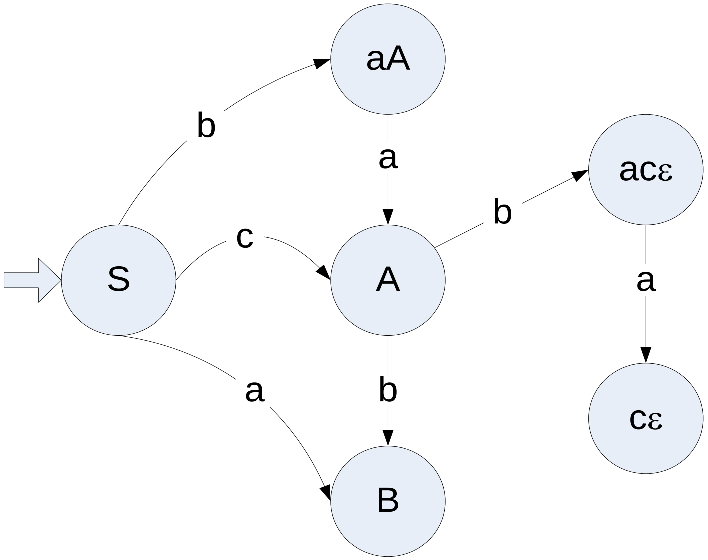

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$S \to cA$
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$[aA] \to aA$
$S \to aB$

$A \to bB$
$A \to b[ac\varepsilon]$
$[ac\varepsilon] \to a[c\varepsilon]$
$[c\varepsilon] \to c[\varepsilon]$
$A \to bS$

$B \to bB$
$B \to b[ac\varepsilon]$
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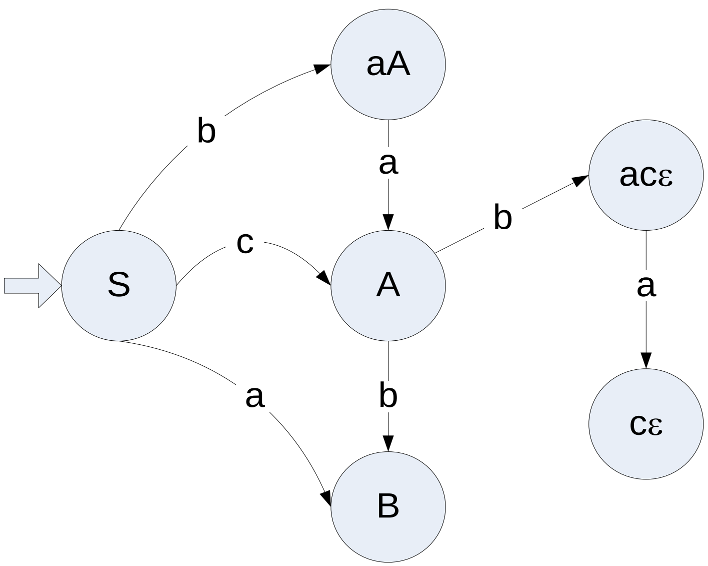

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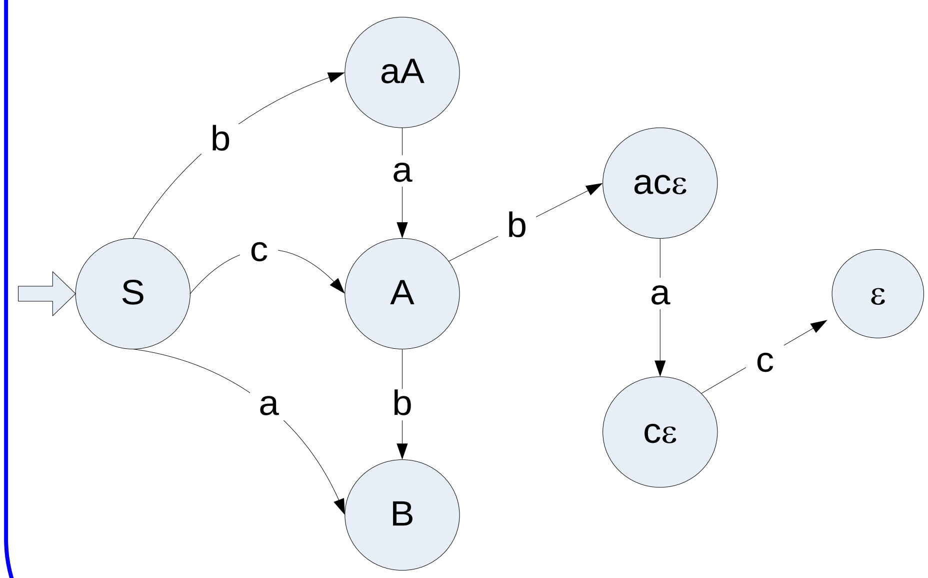
$S \to cA$ $\quad$ $S \to b[aA]$ $\quad$ $[aA] \to aA$ $\quad$ $S \to aB$

$A \to bB$ $\quad$ $A \to b[ac\varepsilon]$ $\quad$ $[ac\varepsilon] \to a[c\varepsilon]$ $\quad$ $[c\varepsilon] \to c[\varepsilon]$ $\quad$ $A \to bS$

$B \to bB$ $\quad$ $B \to b[ac\varepsilon]$ $\quad$ $B \to bS$ $\quad$ $B \to a[c\varepsilon]$ $\quad$ $B \to a[baA]$ $\quad$ $[baA] \to b[aA]$

$[\varepsilon] \to \varepsilon$



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Task 14

3. Construct NFA $\boldsymbol{M_1}$ which accepts sequences generated by the grammar $\boldsymbol{G_3}$

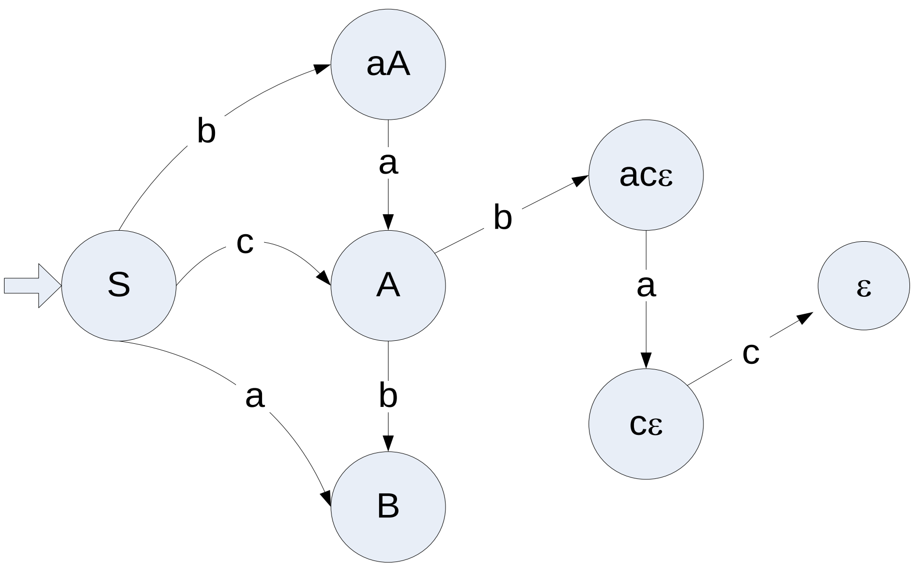
$G_3 = (V_3, T, P_3, S)$

S→cA
S→b[aA]
[aA]→aA
S→aB

A→bB
A→b[acε]
[acε]→a[cε]
[cε]→c[ε]
A→bS

B→bB
B→b[acε]
B→bS
B→a[cε]
B→a[baA]
[baA]→b[aA]

[ε]→ε



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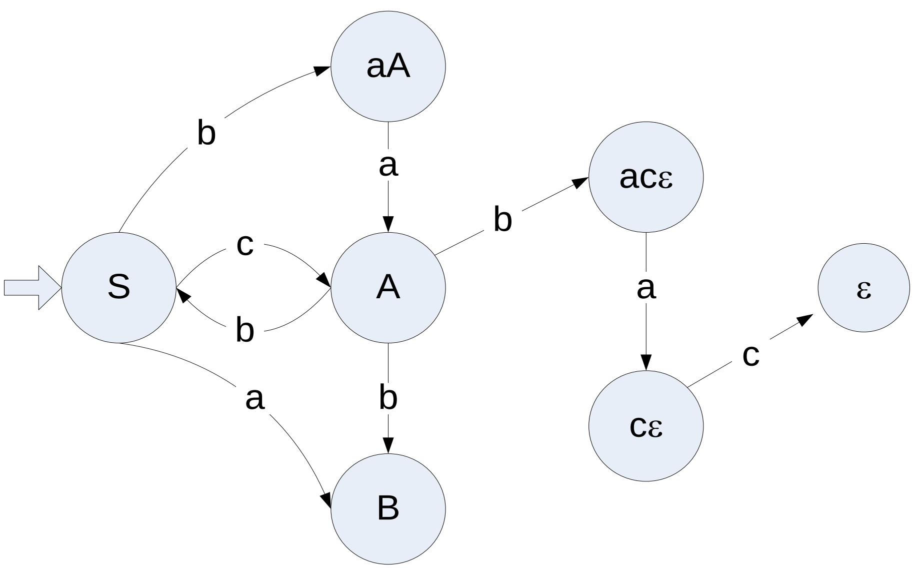
$S \to cA$	$A \to bB$	$B \to bB$	$[\varepsilon] \to \varepsilon$
$S \to b[aA]$	$A \to b[ac\varepsilon]$	$B \to b[ac\varepsilon]$	
$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
	$A \to bS$	$B \to a[baA]$	
		$[baA] \to b[aA]$	



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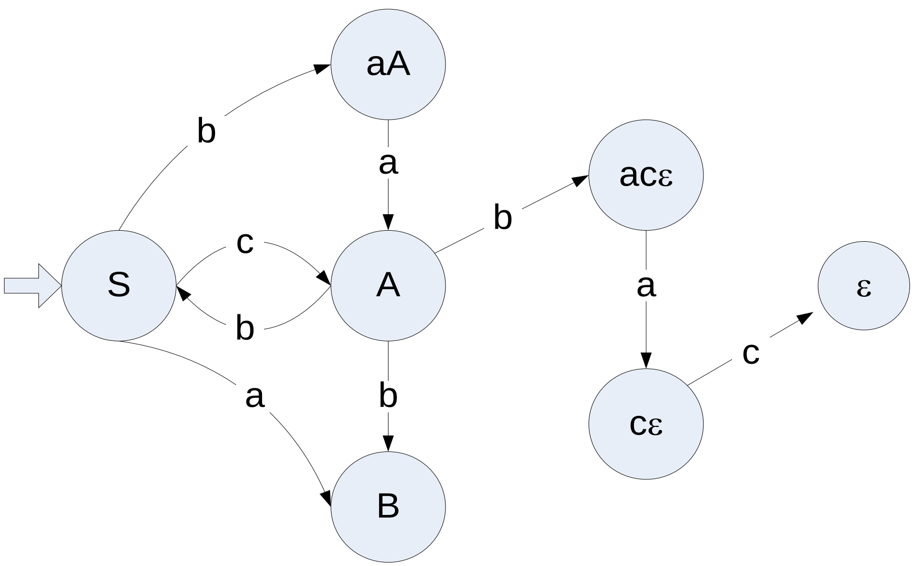
$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
		$B \to a[baA]$	
	$A \to bS$	$[baA] \to b[aA]$	



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$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
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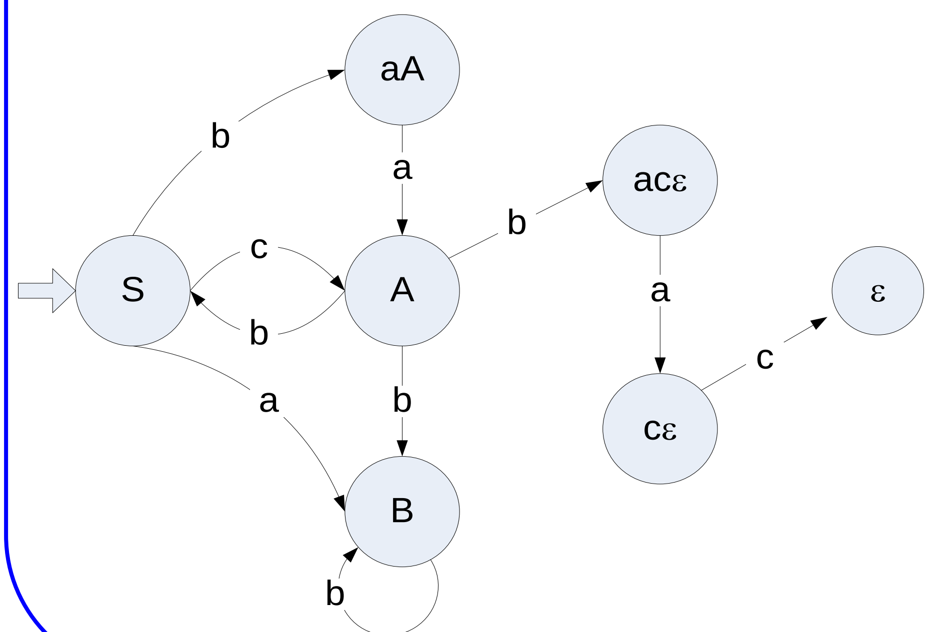
	$A \to bS$	$[baA] \to b[aA]$	



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$[c\varepsilon] \to c[\varepsilon]$
$A \to bS$

$B \to bB$
$B \to b[ac\varepsilon]$
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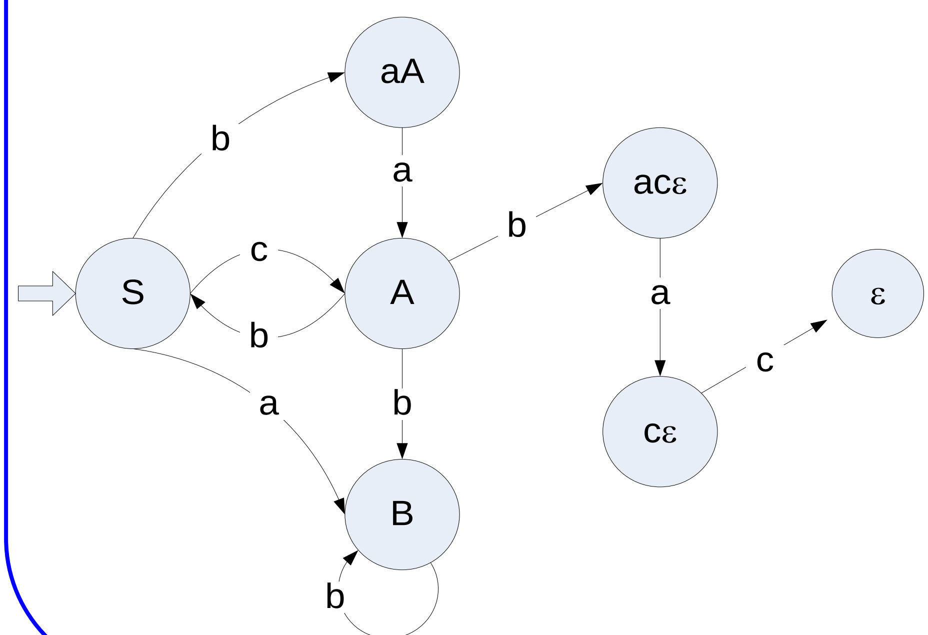

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$[c\varepsilon] \to c[\varepsilon]$
$A \to bS$

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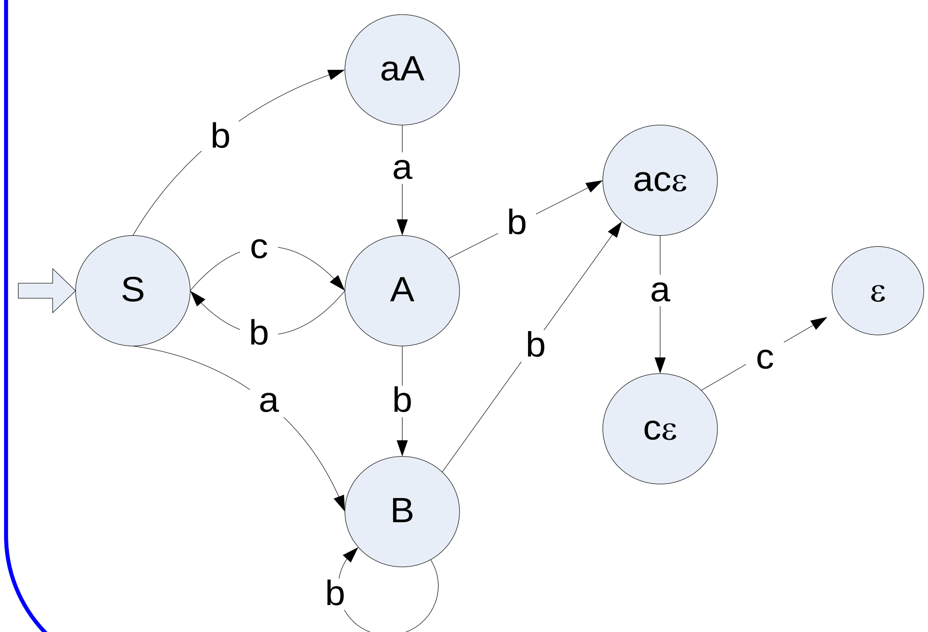

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$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
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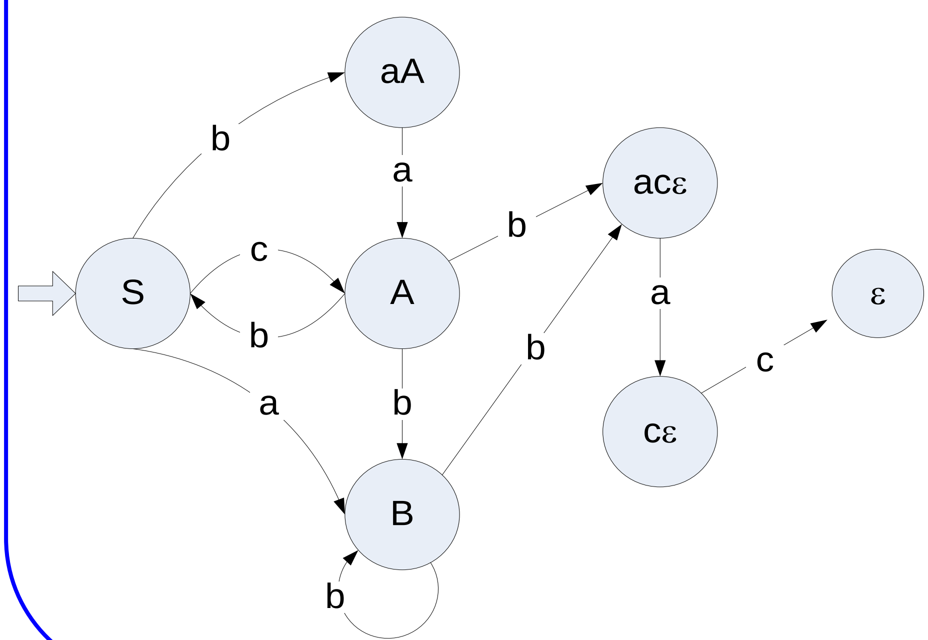
	$A \to bS$	$[baA] \to b[aA]$	



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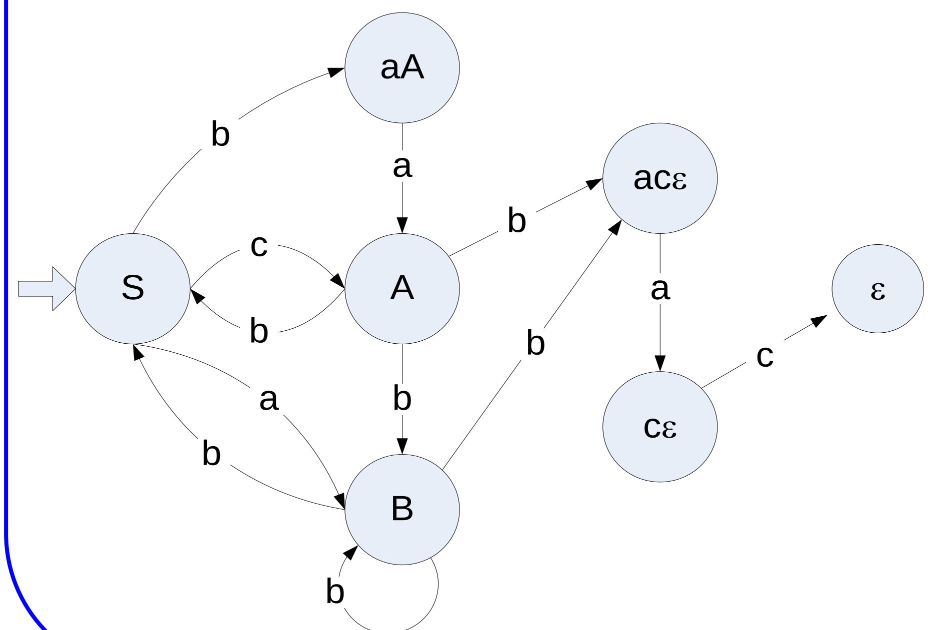
$S \rightarrow aB$

$A \rightarrow bB$
$A \rightarrow b[ac\varepsilon]$
$[ac\varepsilon] \rightarrow a[c\varepsilon]$
$[c\varepsilon] \rightarrow c[\varepsilon]$
$A \rightarrow bS$

$B \rightarrow bB$
$B \rightarrow b[ac\varepsilon]$
$B \rightarrow bS$
$B \rightarrow a[c\varepsilon]$
$B \rightarrow a[baA]$
$[baA] \rightarrow b[aA]$

$[\varepsilon] \rightarrow \varepsilon$



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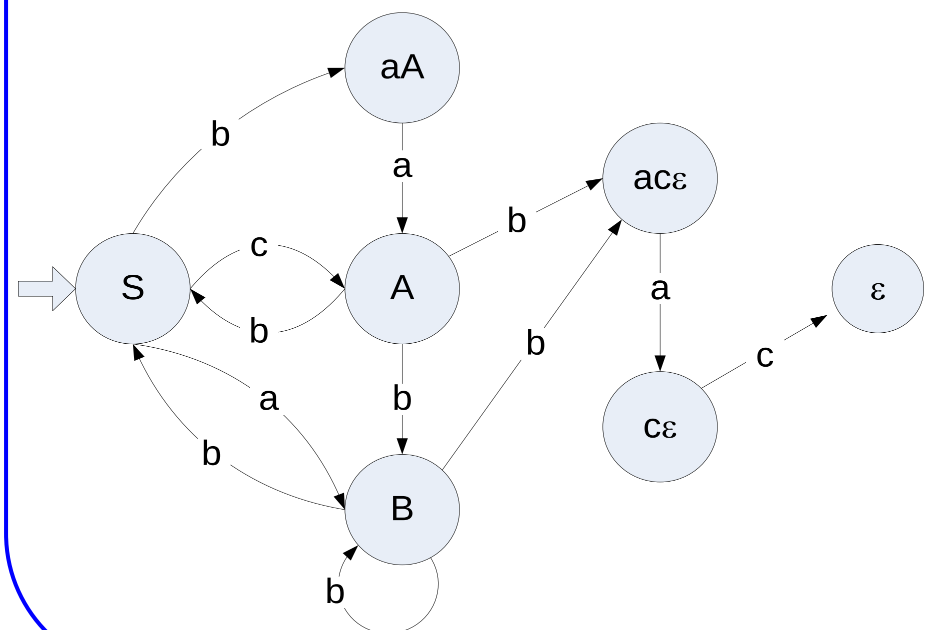
$S \to aB$

$A \to bB$
$A \to b[ac\varepsilon]$
$[ac\varepsilon] \to a[c\varepsilon]$
$[c\varepsilon] \to c[\varepsilon]$
$A \to bS$

$B \to bB$
$B \to b[ac\varepsilon]$
$B \to bS$
$B \to a[c\varepsilon]$
$B \to a[baA]$
$[baA] \to b[aA]$

$[\varepsilon] \to \varepsilon$



NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$

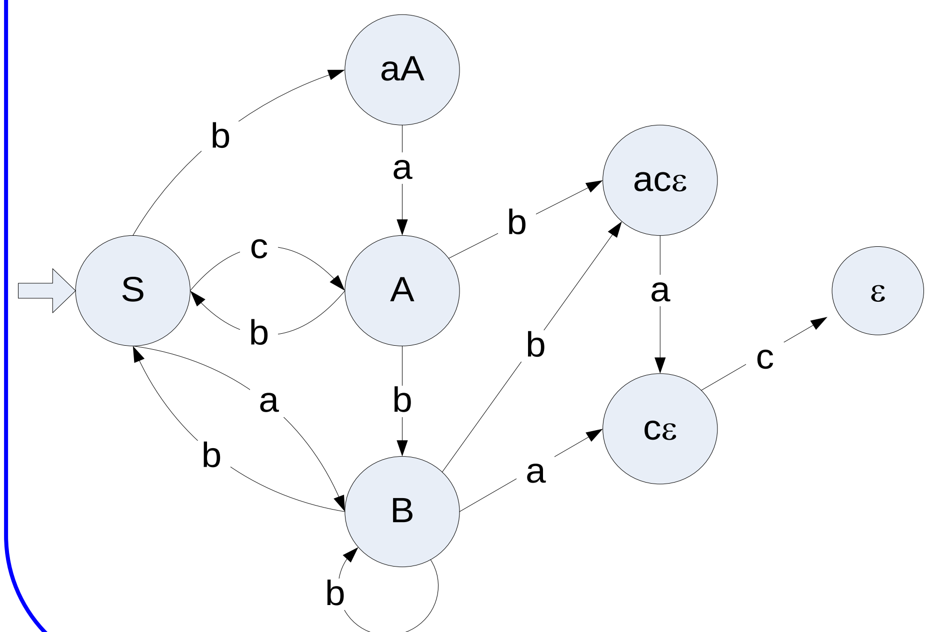
- $Q=V$, $\Sigma=T$, $q_0=S$
- $A \to bC \Rightarrow \delta(A,b)=C$
- $A \to \varepsilon \Rightarrow A \in F$

Task 14

3. Construct NFA $\boldsymbol{M_1}$ which accepts sequences generated by the grammar $\boldsymbol{G_3}$

$\boldsymbol{G_3 = (V_3, T, P_3, S)}$

$S \to cA$	$A \to bB$	$B \to bB$	$[\varepsilon] \to \varepsilon$
$S \to b[aA]$	$A \to b[ac\varepsilon]$	$B \to b[ac\varepsilon]$	
$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
	$A \to bS$	$B \to a[baA]$	
		$[baA] \to b[aA]$	



$\boldsymbol{\text{NFA } M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)}$

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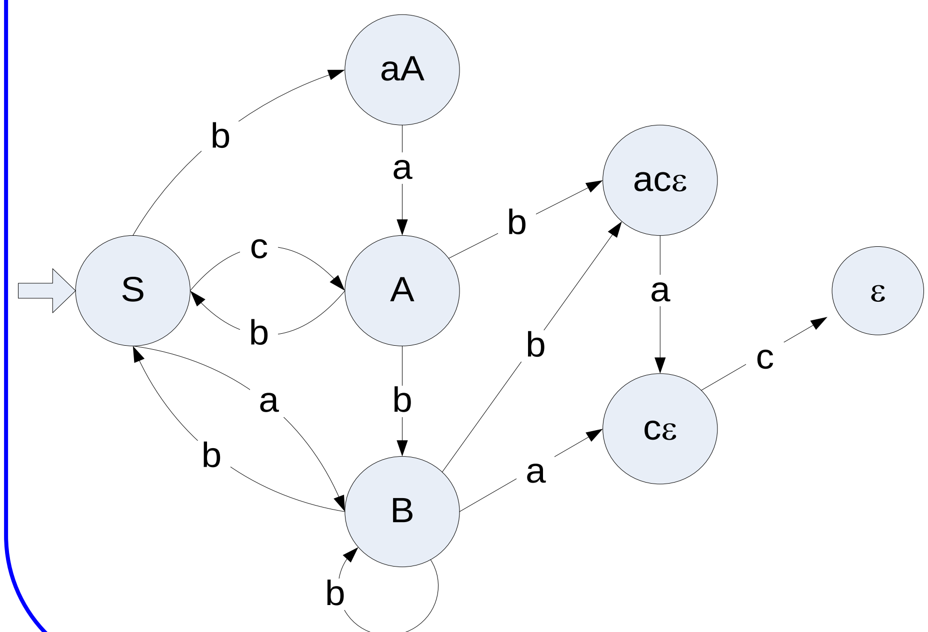
$S \rightarrow cA$
$S \rightarrow b[aA]$
$[aA] \rightarrow aA$
$S \rightarrow aB$

$A \rightarrow bB$
$A \rightarrow b[ac\varepsilon]$
$[ac\varepsilon] \rightarrow a[c\varepsilon]$
$[c\varepsilon] \rightarrow c[\varepsilon]$
$A \rightarrow bS$

$B \rightarrow bB$
$B \rightarrow b[ac\varepsilon]$
$B \rightarrow bS$
$B \rightarrow a[c\varepsilon]$
$B \rightarrow a[baA]$
$[baA] \rightarrow b[aA]$

$[\varepsilon] \rightarrow \varepsilon$



NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$

- $Q=V$, $\Sigma=T$, $q_0=S$
- $A \rightarrow bC \Rightarrow \delta(A,b)=C$
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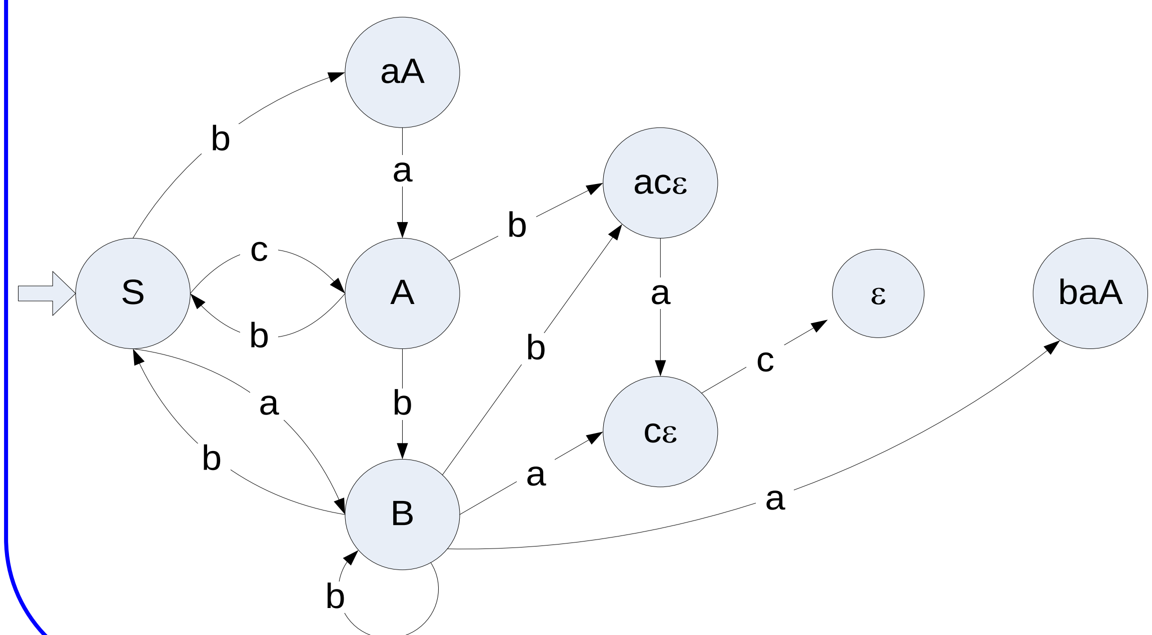
Task 14

3. Construct NFA M_1 which accepts sequences generated by the grammar G_3

$G_3 = (V_3, T, P_3, S)$

$S \to cA$	$A \to bB$	$B \to bB$	$[\varepsilon] \to \varepsilon$
$S \to b[aA]$	$A \to b[ac\varepsilon]$	$B \to b[ac\varepsilon]$	
$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
		$B \to a[baA]$	
	$A \to bS$	$[baA] \to b[aA]$	



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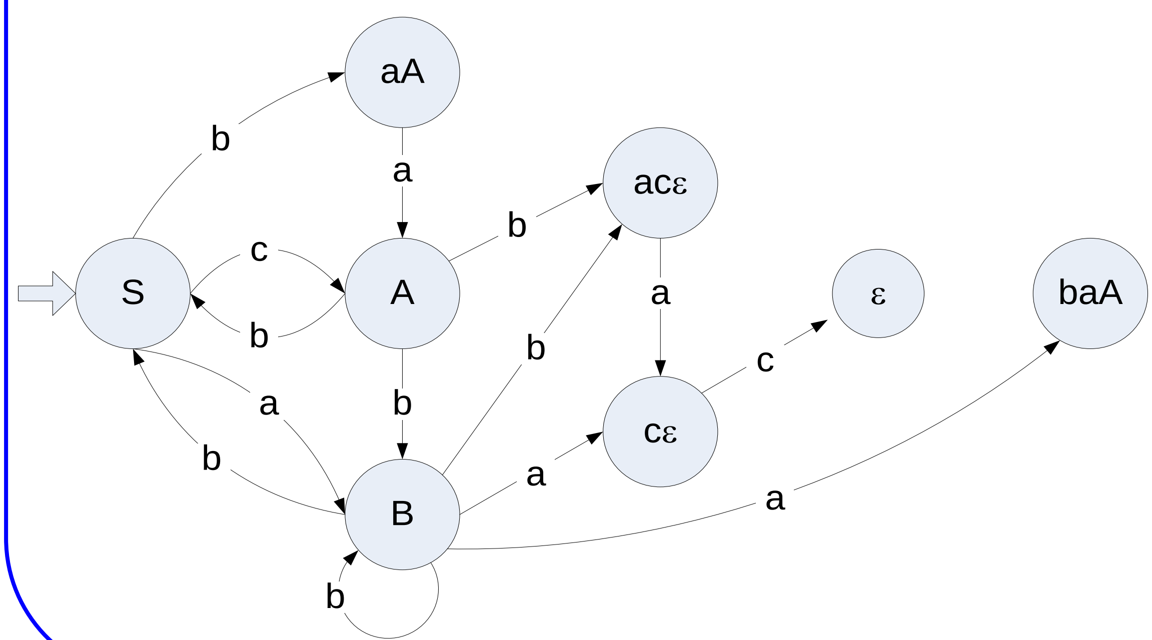
$S \to b[aA]$	$A \to b[ac\varepsilon]$	$B \to b[ac\varepsilon]$	
$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
	$A \to bS$	$B \to a[baA]$	
		$[baA] \to b[aA]$	



NFA $\boldsymbol{M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)}$

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Task 14

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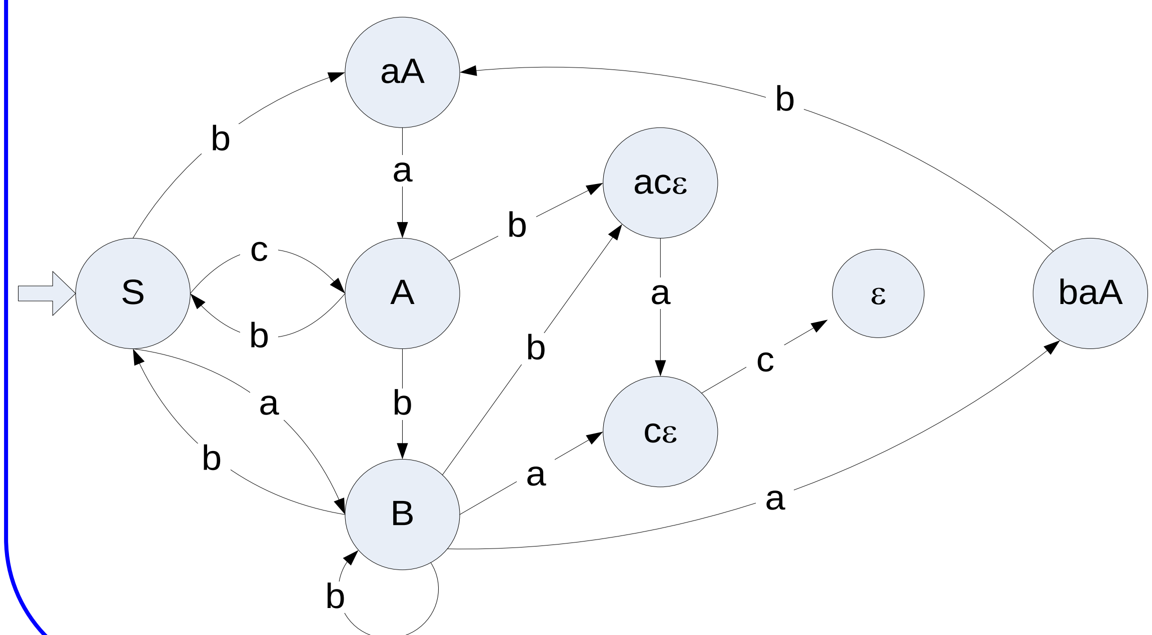
$S \to b[aA]$	$A \to b[ac\varepsilon]$	$B \to b[ac\varepsilon]$	
$[aA] \to aA$	$[ac\varepsilon] \to a[c\varepsilon]$	$B \to bS$	
$S \to aB$	$[c\varepsilon] \to c[\varepsilon]$	$B \to a[c\varepsilon]$	
		$B \to a[baA]$	
	$A \to bS$	$[baA] \to b[aA]$	



NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$

- $Q=V$, $\Sigma=T$, $q_0=S$
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Task 14

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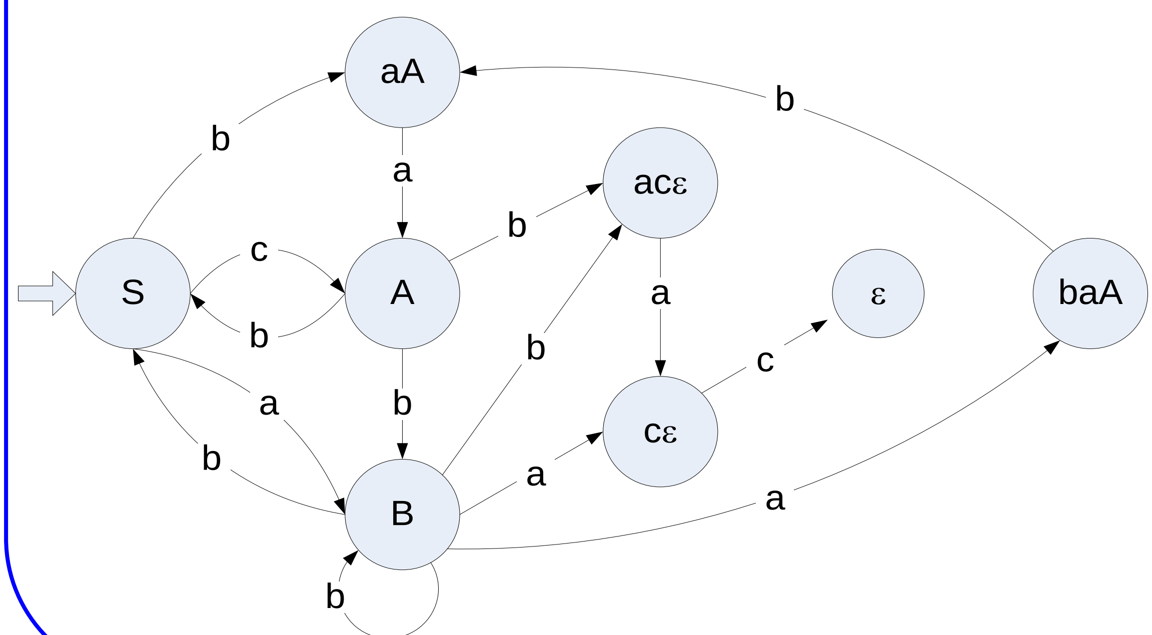
$G_3 = (V_3, T, P_3, S)$

$S \rightarrow cA$
$S \rightarrow b[aA]$
$[aA] \rightarrow aA$
$S \rightarrow aB$

$A \rightarrow bB$
$A \rightarrow b[ac\varepsilon]$
$[ac\varepsilon] \rightarrow a[c\varepsilon]$
$[c\varepsilon] \rightarrow c[\varepsilon]$
$A \rightarrow bS$

$B \rightarrow bB$
$B \rightarrow b[ac\varepsilon]$
$B \rightarrow bS$
$B \rightarrow a[c\varepsilon]$
$B \rightarrow a[baA]$
$[baA] \rightarrow b[aA]$

$[\varepsilon] \rightarrow \varepsilon$



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Task 14

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$G_3 = (V_3, T, P_3, S)$

$S \to cA$ $\quad$ $A \to bB$ $\quad$ $B \to bB$ $\quad$ $[\varepsilon] \to \varepsilon$

$S \to b[aA]$ $\quad$ $A \to b[ac\varepsilon]$ $\quad$ $B \to b[ac\varepsilon]$

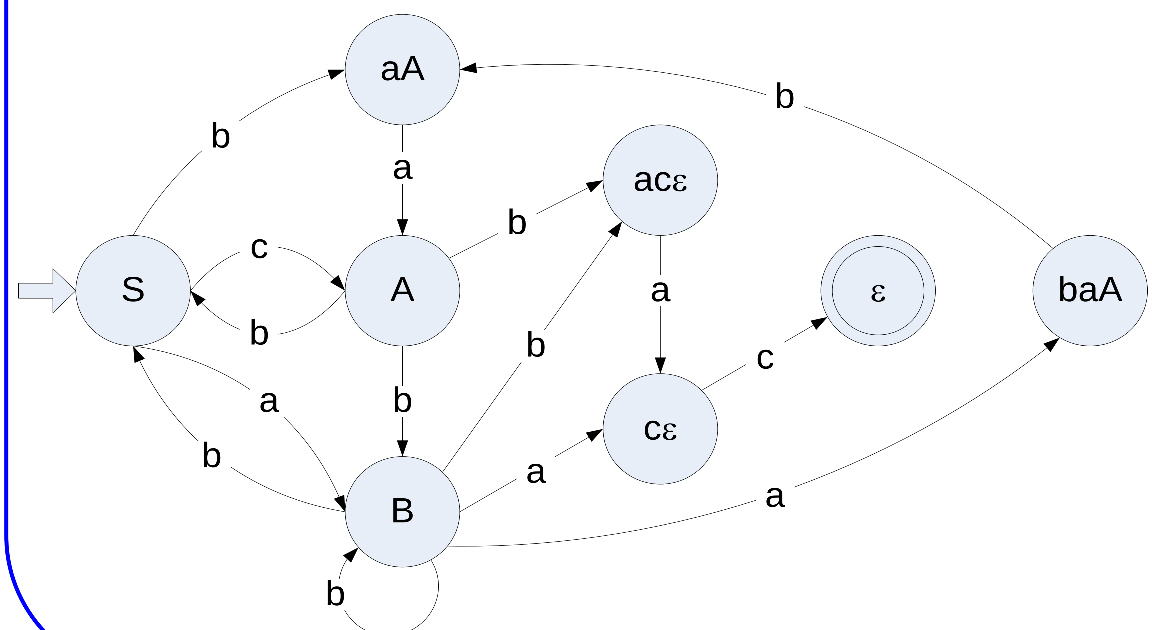
$[aA] \to aA$ $\quad$ $[ac\varepsilon] \to a[c\varepsilon]$ $\quad$ $B \to bS$

$S \to aB$ $\quad$ $[c\varepsilon] \to c[\varepsilon]$ $\quad$ $B \to a[c\varepsilon]$

$B \to a[baA]$

$A \to bS$

$[baA] \to b[aA]$



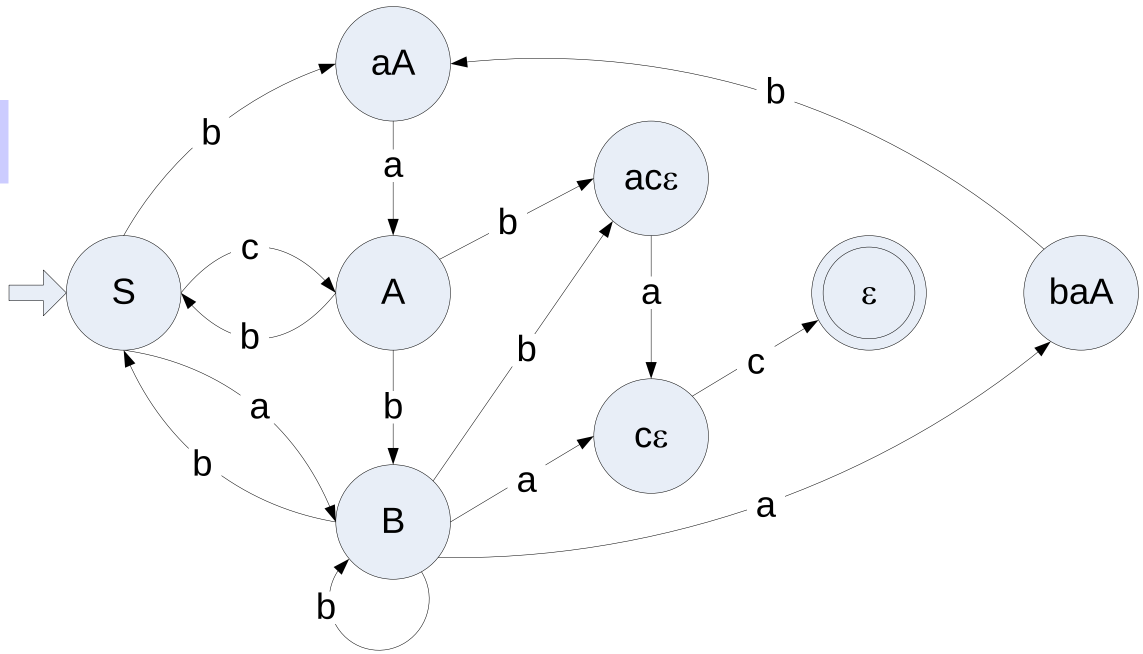
NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$

- $Q=V$, $\Sigma=T$, $q_0=S$
- $A \to bC \Rightarrow \delta(A,b)=C$
- $A \to \varepsilon \Rightarrow A \in F$

Task 14

4. Construct NFA M_2 which accepts sequences written in reverse order compared to those accepted by NFA M_1

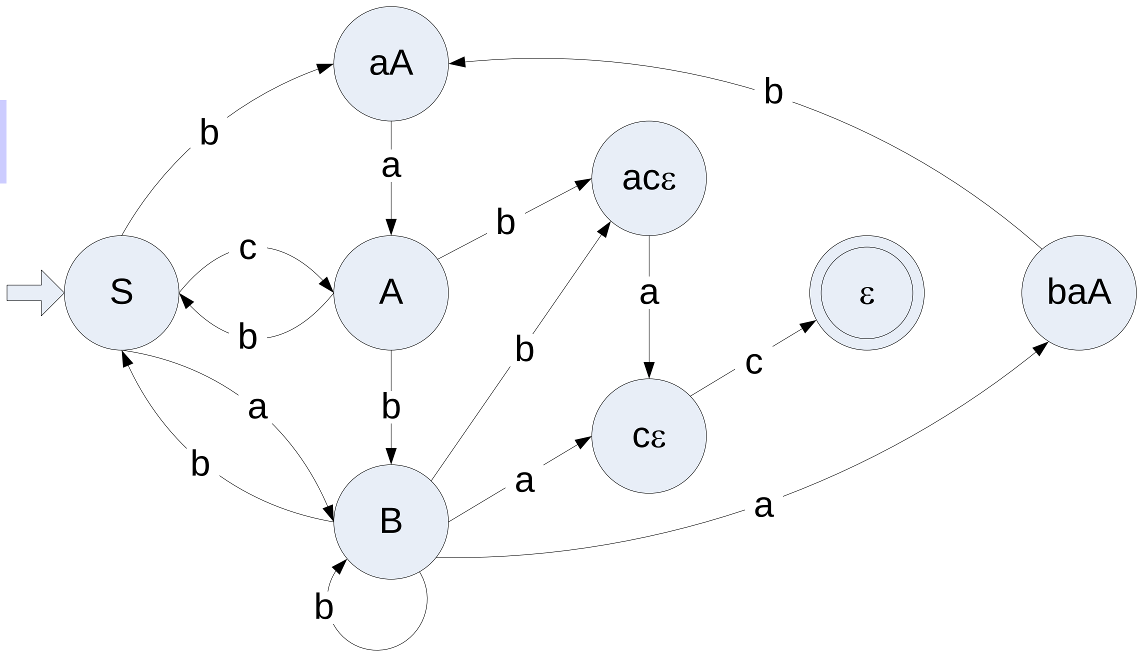
NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$



Task 14

4. Construct NFA $\boldsymbol{M_2}$ which accepts sequences written in reverse order compared to those accepted by NFA $\boldsymbol{M_1}$

NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$

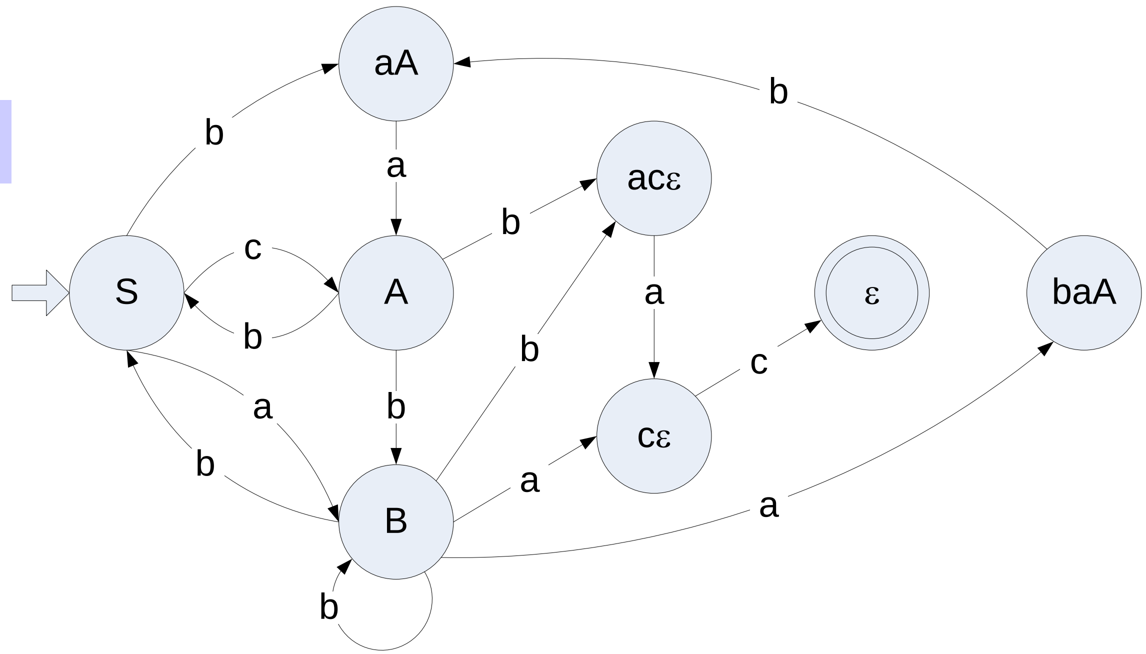


NFA $M_2 = (Q, \Sigma, \delta_2, q_{02}, F_2)$

Task 14

4. Construct NFA $\boldsymbol{M_2}$ which accepts sequences written in reverse order compared to those accepted by NFA $\boldsymbol{M_1}$

NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$



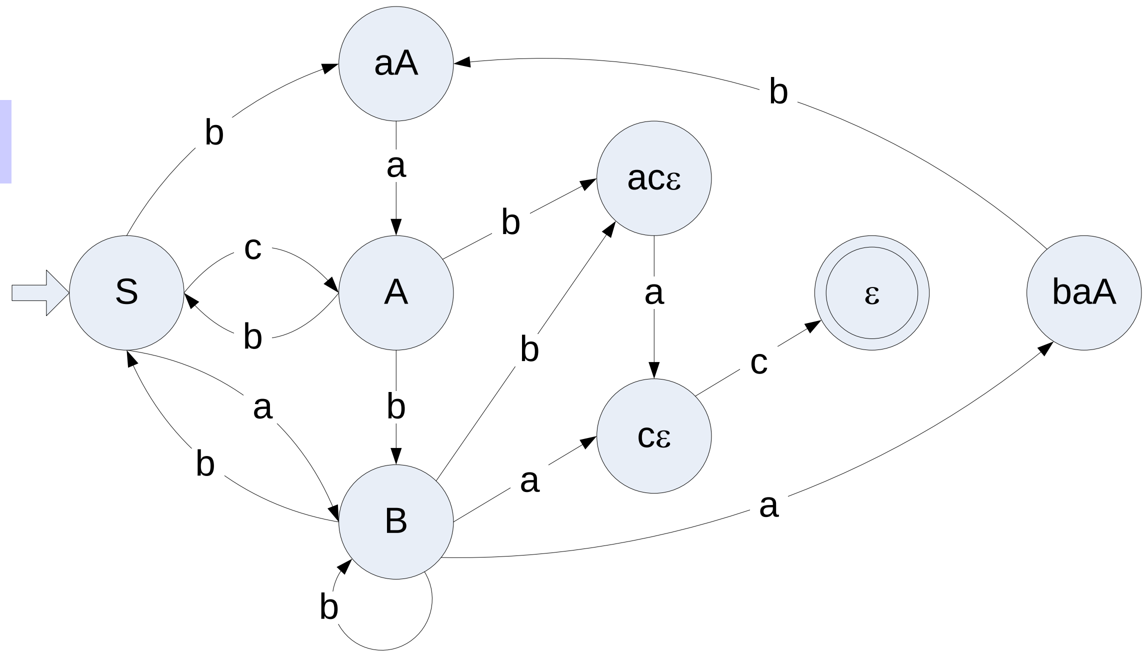
NFA $M_2 = (Q, \Sigma, \delta_2, q_{02}, F_2)$

- □(A,b)=C ⇒ □(C,b)=A
-

Task 14

4. Construct NFA M_2 which accepts sequences written in reverse order compared to those accepted by NFA M_1

NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$



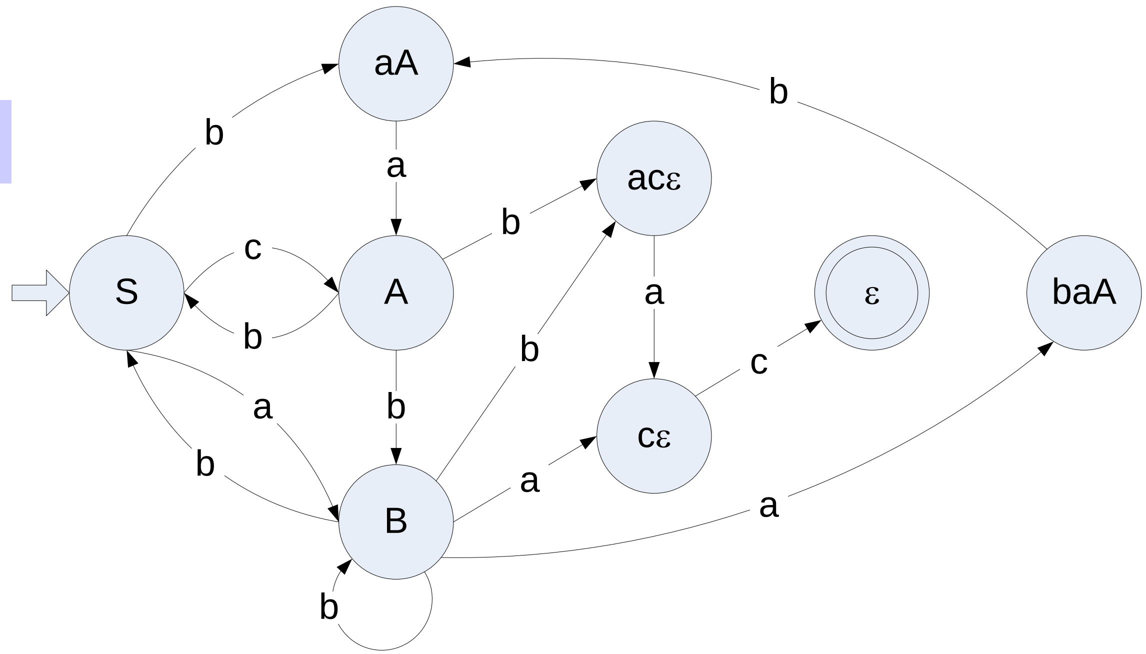
NFA $M_2 = (Q, \Sigma, \delta_2, q_{02}, F_2)$

- □(A,b)=C ⇒ □(C,b)=A
- $q_{02} = F_1$
-

Task 14

4. Construct NFA $\boldsymbol{M_2}$ which accepts sequences written in reverse order compared to those accepted by NFA $\boldsymbol{M_1}$

NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$



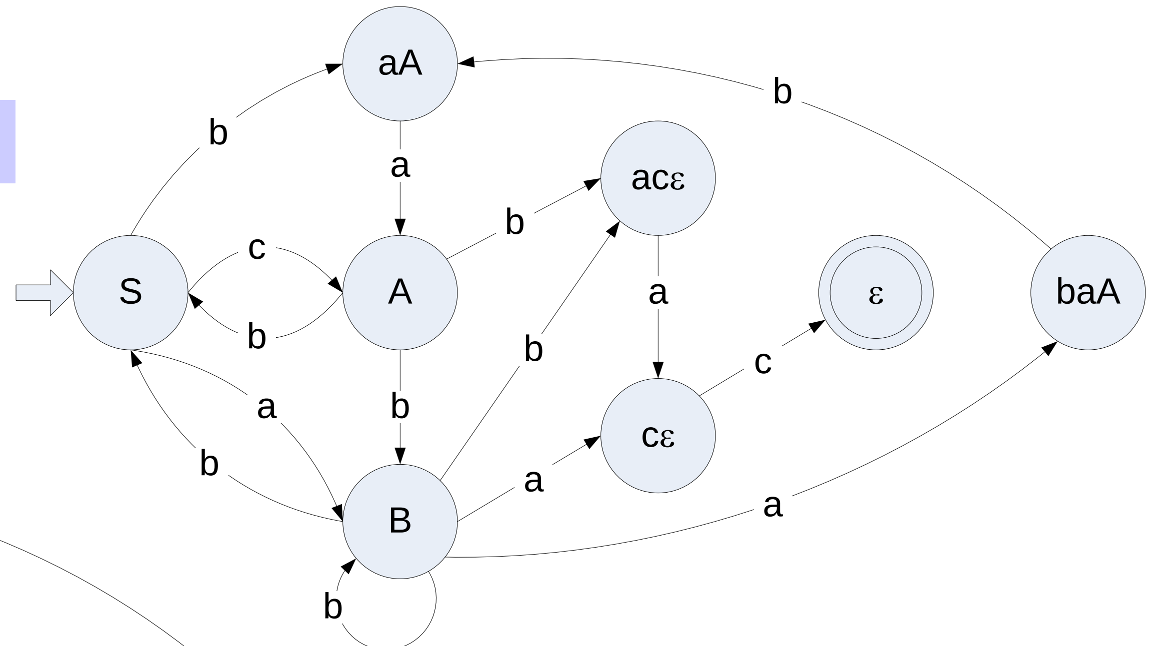
NFA $M_2 = (Q, \Sigma, \delta_2, q_{02}, F_2)$

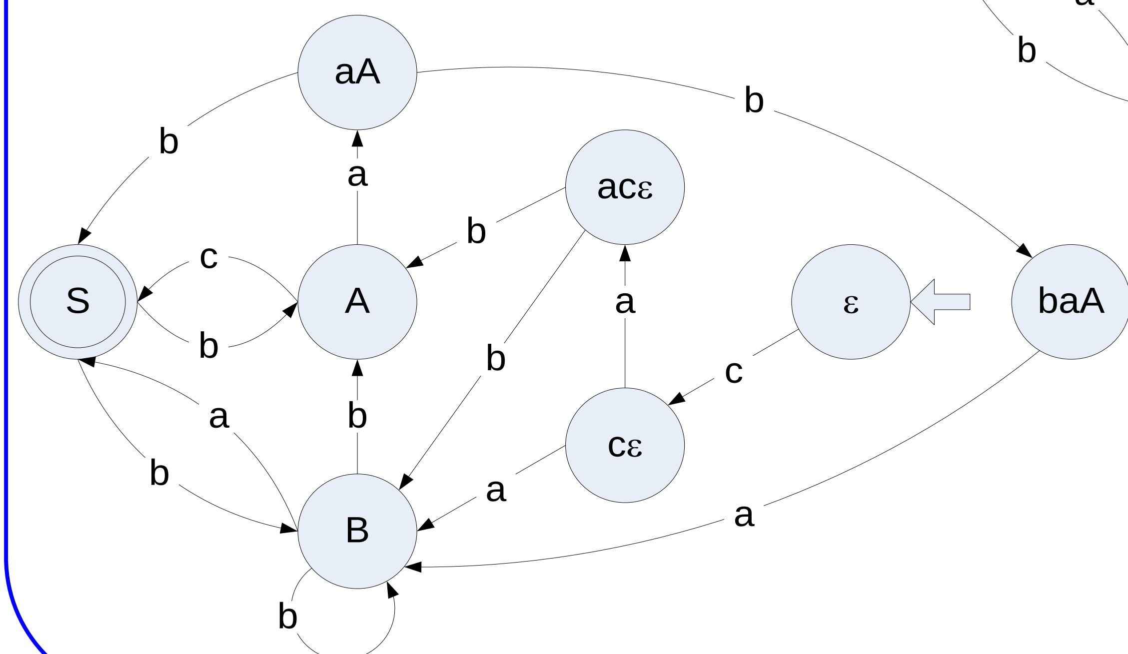
- □(A,b)=C $\Rightarrow$ □(C,b)=A
- $q_{02} = F_1$
- $F_2 = q_{01}$

Task 14

4. Construct NFA M_2 which accepts sequences written in reverse order compared to those accepted by NFA M_1

NFA $M_1 = (Q, \Sigma, \delta_1, q_{01}, F_1)$





NFA $M_2 = (Q, \Sigma, \delta_2, q_{02}, F_2)$

- □(A,b)=C $\Rightarrow$ □(C,b)=A
- $q_{02} = F_1$
- $F_2 = q_{01}$

Task 15

- Convert given grammar G into a left-linear grammar.

$$
\begin{array}{lll}
S \rightarrow xyA & A \rightarrow S & B \rightarrow xS \\
S \rightarrow yxB & A \rightarrow y & B \rightarrow x \\
S \rightarrow B & & \\
S \rightarrow \varepsilon & &
\end{array}
$$

Task 15

- Convert given grammar G into a left-linear grammar.

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\end{array}
$$

Right-linear grammar (RLG)

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Right-linear grammar (RLG)

$$S \Rightarrow u_1A_1$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Right-linear grammar (RLG)

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Right-linear grammar (RLG)

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \dots \Rightarrow u_1u_2\dots u_nA_n$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \rightarrow xyA$	$A \rightarrow S$	$B \rightarrow xS$
$S \rightarrow yxB$	$A \rightarrow y$	$B \rightarrow x$
$S \rightarrow B$		
$S \rightarrow \varepsilon$		

Right-linear grammar (RLG)

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \ldots \Rightarrow u_1u_2\ldots u_nA_n \Rightarrow u_1u_2\ldots u_nu_{n+1}$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Right-linear grammar (RLG) $\Rightarrow$ Generates sequences from left to right,

that is from start to end

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \ldots \Rightarrow u_1u_2\ldots u_nA_n \Rightarrow u_1u_2\ldots u_nu_{n+1}$$

Task 15

- Convert given grammar G into a left-linear grammar.

$$S \to xyA \qquad A \to S \qquad B \to xS$$
$$S \to yxB \qquad A \to y \qquad B \to x$$
$$S \to B$$
$$S \to \varepsilon$$

Right-linear grammar (RLG) $\Rightarrow$ Generates sequences from left to right,

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$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \ldots \Rightarrow u_1u_2\ldots u_nA_n \Rightarrow u_1u_2\ldots u_nu_{n+1}$$

Left-linear grammar (LLG)

Task 15

- Convert given grammar G into a left-linear grammar.

$S \rightarrow xyA$	$A \rightarrow S$	$B \rightarrow xS$
$S \rightarrow yxB$	$A \rightarrow y$	$B \rightarrow x$
$S \rightarrow B$		
$S \rightarrow \varepsilon$		

Right-linear grammar (RLG) $\Rightarrow$ Generates sequences from left to right,

that is from start to end

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \ldots \Rightarrow u_1u_2\ldots u_nA_n \Rightarrow u_1u_2\ldots u_nu_{n+1}$$

Left-linear grammar (LLG)

$$S \Rightarrow B_1v_1$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA \quad A \to S \quad B \to xS$

$S \to yxB \quad A \to y \quad B \to x$

$S \to B$

$S \to \varepsilon$

Right-linear grammar (RLG) $\Rightarrow$ Generates sequences from left to right,

that is from start to end

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \ldots \Rightarrow u_1u_2\ldots u_nA_n \Rightarrow u_1u_2\ldots u_nu_{n+1}$$

Left-linear grammar (LLG)

$$S \Rightarrow B_1v_1 \Rightarrow B_2v_2v_1$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA \qquad A \to S \qquad B \to xS$

$S \to yxB \qquad A \to y \qquad B \to x$

$S \to B$

$S \to \varepsilon$

Right-linear grammar (RLG) $\Rightarrow$ Generates sequences from left to right,

that is from start to end

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \ldots \Rightarrow u_1u_2\ldots u_nA_n \Rightarrow u_1u_2\ldots u_nu_{n+1}$$

Left-linear grammar (LLG)

$$S \Rightarrow B_1v_1 \Rightarrow B_2v_2v_1 \Rightarrow \ldots \Rightarrow B_nv_n\ldots v_2v_1$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Right-linear grammar (RLG) $\Rightarrow$ Generates sequences from left to right,

that is from start to end

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \ldots \Rightarrow u_1u_2\ldots u_nA_n \Rightarrow u_1u_2\ldots u_nu_{n+1}$$

Left-linear grammar (LLG)

$$S \Rightarrow B_1v_1 \Rightarrow B_2v_2v_1 \Rightarrow \ldots \Rightarrow B_nv_n\ldots v_2v_1 \Rightarrow v_{n+1}v_n\ldots v_2v_1$$

Task 15

- Convert given grammar G into a left-linear grammar.

$$
\begin{array}{lll}
S \to xyA & A \to S & B \to xS \\
S \to yxB & A \to y & B \to x \\
S \to B & & \\
S \to \varepsilon & &
\end{array}
$$

Right-linear grammar (RLG) $\Rightarrow$ Generates sequences from left to right,

that is from start to end

$$S \Rightarrow u_1A_1 \Rightarrow u_1u_2A_2 \Rightarrow \ldots \Rightarrow u_1u_2\ldots u_nA_n \Rightarrow u_1u_2\ldots u_nu_{n+1}$$

Left-linear grammar (LLG) $\Rightarrow$ Generates sequences from right to left,

that is from end to start

$$S \Rightarrow B_1v_1 \Rightarrow B_2v_2v_1 \Rightarrow \ldots \Rightarrow B_nv_n\ldots v_2v_1 \Rightarrow v_{n+1}v_n\ldots v_2v_1$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Task 15

- Convert given grammar G into a left-linear grammar.

$$
\begin{array}{lll}
S \to xyA & A \to S & B \to xS \\
S \to yxB & A \to y & B \to x \\
S \to B & & \\
S \to \varepsilon & &
\end{array}
$$

Grammar G $\Rightarrow$ right-linear grammar

Task 15

- Convert given grammar G into a left-linear grammar.

$$S \rightarrow xyA \qquad A \rightarrow S \qquad B \rightarrow xS$$
$$S \rightarrow yxB \qquad A \rightarrow y \qquad B \rightarrow x$$
$$S \rightarrow B$$
$$S \rightarrow \varepsilon$$

Grammar G $\Rightarrow$ right-linear grammar

Task $\Rightarrow$ construct grammar which generates sequences in opposite direction

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Grammar G $\Rightarrow$ right-linear grammar

Task $\Rightarrow$ construct grammar which generates sequences in opposite direction

Step 1:

Task 15

- Convert given grammar G into a left-linear grammar.

$$S \to xyA \qquad A \to S \qquad B \to xS$$
$$S \to yxB \qquad A \to y \qquad B \to x$$
$$S \to B$$
$$S \to \varepsilon$$

Grammar G $\Rightarrow$ right-linear grammar

Task $\Rightarrow$ construct grammar which generates sequences in opposite direction

Step 1:

In the set of non-terminal symbols LLG we add new non-terminal symbol F which starts sequence generation from end to start.

Task 15

- Convert given grammar G into a left-linear grammar.

$$
\begin{array}{lll}
S \to xyA & A \to S & B \to xS \\
S \to yxB & A \to y & B \to x \\
S \to B & & \\
S \to \varepsilon & &
\end{array}
$$

Grammar G $\Rightarrow$ right-linear grammar

Task $\Rightarrow$ construct grammar which generates sequences in opposite direction

Step 1:

In the set of non-terminal symbols LLG we add new non-terminal symbol F which starts sequence generation from end to start.

$$LLG=(V_{LLG},T_{LLG},P_{LLG},F)$$

Task 15

- Convert given grammar G into a left-linear grammar.

$$
\begin{array}{lll}
S \rightarrow xyA & A \rightarrow S & B \rightarrow xS \\
S \rightarrow yxB & A \rightarrow y & B \rightarrow x \\
S \rightarrow B & & \\
S \rightarrow \varepsilon & &
\end{array}
$$

Grammar G $\Rightarrow$ right-linear grammar

Task $\Rightarrow$ construct grammar which generates sequences in opposite direction

Step 1:

In the set of non-terminal symbols LLG we add new non-terminal symbol F which starts sequence generation from end to start.

$$LLG=(V_{LLG},T_{LLG},P_{LLG},F)$$

$$V_{LLG}= V_{RLG} \cup \{F\} = \{S,A,B,F\}$$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Grammar G $\Rightarrow$ right-linear grammar

Task $\Rightarrow$ construct grammar which generates sequences in opposite direction

Step 1:

In the set of non-terminal symbols LLG we add new non-terminal symbol F which starts sequence generation from end to start.

$LLG=(V_{LLG},T_{LLG},P_{LLG},F)$

$V_{LLG}= V_{RLG} \cup \{F\} = \{S,A,B,F\}$

$T_{LLG} = T_{RLG}$

Task 15

- Convert given grammar G into a left-linear grammar.

$$S \to xyA \qquad A \to S \qquad B \to xS$$
$$S \to yxB \qquad A \to y \qquad B \to x$$
$$S \to B$$
$$S \to \varepsilon$$

Grammar G $\Rightarrow$ right-linear grammar

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In the set of non-terminal symbols LLG we add new non-terminal symbol F which starts sequence generation from end to start.

$LLG=(V_{LLG},T_{LLG},P_{LLG},F)$

$V_{LLG}= V_{RLG} \cup \{F\} = \{S,A,B,F\}$

$T_{LLG} = T_{RLG}$

F is the starting non-terminal symbol in LLG

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 2:

Task 15

- Convert given grammar G into a left-linear grammar.

$$S \to xyA \qquad A \to S \qquad B \to xS$$
$$S \to yxB \qquad A \to y \qquad B \to x$$
$$S \to B$$
$$S \to \varepsilon$$

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon$	$\Rightarrow$	$F \to A$	$A \in V$
for $A \to a_1 a_2 \ldots a_n$	$\Rightarrow$	$F \to A\, a_1 a_2 \ldots a_n$	$A \in V,\ a_i \in T$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon$	$\Rightarrow$	$F \to A$	$A \in V$
for $A \to a_1 a_2 \ldots a_n$	$\Rightarrow$	$F \to A\, a_1 a_2 \ldots a_n$	$A \in V,\ a_i \in T$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon$	$\Rightarrow$	$F \to A$	$A \in V$
for $A \to a_1 a_2 \ldots a_n$	$\Rightarrow$	$F \to A\, a_1 a_2 \ldots a_n$	$A \in V,\ a_i \in T$

$F \to S$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA \quad A \to S \quad B \to xS$

$S \to yxB \quad A \to y \quad B \to x$

$S \to B$

$S \to \varepsilon$

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon \quad \Rightarrow \quad F \to A \quad A \in V$

for $A \to a_1 a_2 \ldots a_n \Rightarrow \quad F \to A\, a_1 a_2 \ldots a_n \quad A \in V,\ a_i \in T$

$F \to S$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon$	$\Rightarrow$	$F \to A$	$A \in V$
for $A \to a_1a_2...a_n$	$\Rightarrow$	$F \to A\, a_1a_2...a_n$	$A \in V,\ a_i \in T$

$F \to S$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon$	$\Rightarrow$	$F \to A$	$A \in V$
for $A \to a_1 a_2 \ldots a_n$	$\Rightarrow$	$F \to A\ a_1 a_2 \ldots a_n$	$A \in V,\ a_i \in T$

$F \to S$

$F \to Ay$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon \quad \Rightarrow \quad F \to A \quad A \in V$

for $A \to a_1 a_2 \ldots a_n \quad \Rightarrow \quad F \to A\, a_1 a_2 \ldots a_n \quad A \in V,\ a_i \in T$

$F \to S$

$F \to Ay$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon \quad \Rightarrow \quad F \to A \qquad A \in V$

for $A \to a_1a_2...a_n \Rightarrow \quad F \to A\, a_1a_2...a_n \qquad A \in V,\ a_i \in T$

$F \to S$

$F \to Ay$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \rightarrow xyA$	$A \rightarrow S$	$B \rightarrow xS$
$S \rightarrow yxB$	$A \rightarrow y$	$B \rightarrow x$
$S \rightarrow B$		
$S \rightarrow \varepsilon$		

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \rightarrow \varepsilon$	$\Rightarrow$	$F \rightarrow A$	$A \in V$
for $A \rightarrow a_1 a_2 \ldots a_n$	$\Rightarrow$	$F \rightarrow A\, a_1 a_2 \ldots a_n$	$A \in V$, $a_i \in T$

$F \rightarrow S$

$F \rightarrow Ay$

$F \rightarrow Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 2:

We add production rules from symbol F into all non-terminal symbols which have only terminal symbols or ε on the right side of their production rules:

for $A \to \varepsilon \quad \Rightarrow \quad F \to A \quad A \in V$

for $A \to a_1 a_2 \ldots a_n \Rightarrow \quad F \to A\, a_1 a_2 \ldots a_n \quad A \in V,\ a_i \in T$

$F \to S$

$F \to Ay$

$F \to Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \rightarrow xyA$	$A \rightarrow S$	$B \rightarrow xS$
$S \rightarrow yxB$	$A \rightarrow y$	$B \rightarrow x$
$S \rightarrow B$		
$S \rightarrow \varepsilon$		

Step 3:

$F \rightarrow S$

$F \rightarrow Ay$

$F \rightarrow Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \rightarrow xyA$ $A \rightarrow S$ $B \rightarrow xS$

$S \rightarrow yxB$ $A \rightarrow y$ $B \rightarrow x$

$S \rightarrow B$

$S \rightarrow \varepsilon$

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \rightarrow B$ $\Rightarrow$ $B \rightarrow A$ $A,B \in V$

for $A \rightarrow a_1 a_2 \ldots a_n B$ $\Rightarrow$ $B \rightarrow A\ a_1 a_2 \ldots a_n$ $A,B \in V,\ a_i \in T$

$F \rightarrow S$

$F \rightarrow Ay$

$F \rightarrow Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$ $\Rightarrow$ $B \to A$ $A, B \in V$

for $A \to a_1 a_2 \ldots a_n B$ $\Rightarrow$ $B \to A\, a_1 a_2 \ldots a_n$ $A, B \in V,\ a_i \in T$

$F \to S$

$F \to Ay$

$F \to Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \rightarrow xyA$	$A \rightarrow S$	$B \rightarrow xS$
$S \rightarrow yxB$	$A \rightarrow y$	$B \rightarrow x$
$S \rightarrow B$		
$S \rightarrow \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \rightarrow B$	$\Rightarrow$	$B \rightarrow A$	$A,B \in V$
for $A \rightarrow a_1a_2...a_nB$	$\Rightarrow$	$B \rightarrow A\ a_1a_2...a_n$	$A,B \in V,\ a_i \in T$

$F \rightarrow S$ $\quad$ $S \rightarrow Bx$

$F \rightarrow Ay$

$F \rightarrow Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$	$\Rightarrow$	$B \to A$	$A,B \in V$
for $A \to a_1a_2...a_nB$	$\Rightarrow$	$B \to A\ a_1a_2...a_n$	$A,B \in V,\ a_i \in T$

$F \to S$ $\qquad$ $S \to Bx$

$F \to Ay$

$F \to Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \rightarrow xyA$ $\quad A \rightarrow S$ $\quad B \rightarrow xS$

$S \rightarrow yxB$ $\quad A \rightarrow y$ $\quad B \rightarrow x$

$S \rightarrow B$

$S \rightarrow \varepsilon$

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \rightarrow B$	$\Rightarrow$	$B \rightarrow A$	$A,B \in V$
for $A \rightarrow a_1 a_2 \ldots a_n B$	$\Rightarrow$	$B \rightarrow A\ a_1 a_2 \ldots a_n$	$A,B \in V,\ a_i \in T$

$F \rightarrow S$ $\qquad S \rightarrow Bx$

$F \rightarrow Ay$

$F \rightarrow Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$ | $A \to S$ | $B \to xS$
$S \to yxB$ | $A \to y$ | $B \to x$
$S \to B$
$S \to \varepsilon$

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$ $\Rightarrow$ $B \to A$ $A,B \in V$

for $A \to a_1 a_2 \ldots a_n B$ $\Rightarrow$ $B \to A\ a_1 a_2 \ldots a_n$ $A,B \in V,\ a_i \in T$

$F \to S$ $S \to Bx$

$F \to Ay$

$F \to Bx$ $S \to A$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$	$\Rightarrow$	$B \to A$	$A,B \in V$
for $A \to a_1 a_2 \ldots a_n B$	$\Rightarrow$	$B \to A\, a_1 a_2 \ldots a_n$	$A,B \in V,\ a_i \in T$

$F \to S$	$S \to Bx$
$F \to Ay$	
$F \to Bx$	$S \to A$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$	$\Rightarrow$	$B \to A$	$A,B \in V$
for $A \to a_1 a_2 \ldots a_n B$	$\Rightarrow$	$B \to A\ a_1 a_2 \ldots a_n$	$A,B \in V$, $a_i \in T$

$F \to S$ $\quad$ $S \to Bx$

$F \to Ay$

$F \to Bx$ $\quad$ $S \to A$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$	$\Rightarrow$	$B \to A$	$A,B \in V$
for $A \to a_1 a_2 \ldots a_n B$	$\Rightarrow$	$B \to A\, a_1 a_2 \ldots a_n$	$A,B \in V,\ a_i \in T$

$F \to S$	$S \to Bx$	$A \to Sxy$
$F \to Ay$		
$F \to Bx$	$S \to A$	

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$ $\Rightarrow$ $B \to A$ $A,B \in V$

for $A \to a_1a_2 \ldots a_nB$ $\Rightarrow$ $B \to A\, a_1a_2 \ldots a_n$ $A,B \in V,\ a_i \in T$

$F \to S$ $S \to Bx$ $A \to Sxy$

$F \to Ay$

$F \to Bx$ $S \to A$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$	$\Rightarrow$	$B \to A$	$A,B \in V$
for $A \to a_1a_2\ldots a_nB$	$\Rightarrow$	$B \to A\ a_1a_2\ldots a_n$	$A,B \in V,\ a_i \in T$

$F \to S$ $\quad S \to Bx$ $\quad A \to Sxy$

$F \to Ay$

$F \to Bx$ $\quad S \to A$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$ $\Rightarrow$ $B \to A$ $A, B \in V$

for $A \to a_1 a_2 \ldots a_n B$ $\Rightarrow$ $B \to A\ a_1 a_2 \ldots a_n$ $A, B \in V,\ a_i \in T$

$F \to S$ $S \to Bx$ $A \to Sxy$ $B \to S$

$F \to Ay$

$F \to Bx$ $S \to A$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$ $\Rightarrow$ $B \to A$ $A,B \in V$

for $A \to a_1a_2...a_nB$ $\Rightarrow$ $B \to A\ a_1a_2...a_n$ $A,B \in V,\ a_i \in T$

$F \to S$ $S \to Bx$ $A \to Sxy$ $B \to S$

$F \to Ay$

$F \to Bx$ $S \to A$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \rightarrow xyA$	$A \rightarrow S$	$B \rightarrow xS$
$S \rightarrow yxB$	$A \rightarrow y$	$B \rightarrow x$
$S \rightarrow B$		
$S \rightarrow \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \rightarrow B$	$\Rightarrow$	$B \rightarrow A$	$A,B \in V$
for $A \rightarrow a_1a_2 \ldots a_nB$	$\Rightarrow$	$B \rightarrow A\ a_1a_2 \ldots a_n$	$A,B \in V,\ a_i \in T$

$F \rightarrow S$	$S \rightarrow Bx$	$A \rightarrow Sxy$	$B \rightarrow S$
$F \rightarrow Ay$			
$F \rightarrow Bx$	$S \rightarrow A$		

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$ $\Rightarrow$ $B \to A$ $A,B \in V$

for $A \to a_1 a_2 \ldots a_n B$ $\Rightarrow$ $B \to A\ a_1 a_2 \ldots a_n$ $A,B \in V,\ a_i \in T$

$F \to S$ $S \to Bx$ $A \to Sxy$ $B \to S$

$F \to Ay$ $B \to Syx$

$F \to Bx$ $S \to A$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 3:

In all other productions we reverse the order of generating sub-sequences so that productions generate sub-sequences from end to start:

for $A \to B$	$\Rightarrow$	$B \to A$	$A, B \in V$
for $A \to a_1 a_2 \ldots a_n B$	$\Rightarrow$	$B \to A\ a_1 a_2 \ldots a_n$	$A, B \in V,\ a_i \in T$

$F \to S$	$S \to Bx$	$A \to Sxy$	$B \to S$
$F \to Ay$			$B \to Syx$
$F \to Bx$	$S \to A$		

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA \quad A \to S \quad B \to xS$

$S \to yxB \quad A \to y \quad B \to x$

$S \to B$

$S \to \varepsilon$

Step 4:

$F \to S \quad S \to Bx \quad A \to Sxy \quad B \to S$

$F \to Ay \quad S \to A \quad B \to Syx$

$F \to Bx$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 4:

In the set of production rules LLG we add production rule $S \to \varepsilon$ which is the only production rule that ends sequence generation in LLG.

$F \to S$	$S \to Bx$	$A \to Sxy$	$B \to S$
$F \to Ay$	$S \to A$		$B \to Syx$
$F \to Bx$			

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Step 4:

In the set of production rules LLG we add production rule $S \to \varepsilon$ which is the only production rule that ends sequence generation in LLG.

$F \to S$	$S \to Bx$	$A \to Sxy$	$B \to S$
$F \to Ay$	$S \to A$		$B \to Syx$
$F \to Bx$	$S \to \varepsilon$		

Task 15

- Convert given grammar G into a left-linear grammar.

$$S \to xyA \qquad A \to S \qquad B \to xS$$
$$S \to yxB \qquad A \to y \qquad B \to x$$
$$S \to B$$
$$S \to \varepsilon$$

Extra step:

$F \to S$	$S \to Bx$	$A \to Sxy$	$B \to S$
$F \to Ay$	$S \to A$		$B \to Syx$
$F \to Bx$	$S \to \varepsilon$		

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA \qquad A \to S \qquad B \to xS$

$S \to yxB \qquad A \to y \qquad B \to x$

$S \to B$

$S \to \varepsilon$

Extra step:

Replace $F \Rightarrow S'$ and $S \Rightarrow F'$ so that LLG has starting non-terminal symbol S'.

$F \to S \qquad S \to Bx \qquad A \to Sxy \qquad B \to S$

$F \to Ay \qquad S \to A \qquad B \to Syx$

$F \to Bx \qquad S \to \varepsilon$

Task 15

- Convert given grammar G into a left-linear grammar.

$S \to xyA$	$A \to S$	$B \to xS$
$S \to yxB$	$A \to y$	$B \to x$
$S \to B$		
$S \to \varepsilon$		

Extra step:

Replace $F \Rightarrow S'$ and $S \Rightarrow F'$ so that LLG has starting non-terminal symbol S'.

$F \to S$	$S \to Bx$	$A \to Sxy$	$B \to S$
$F \to Ay$	$S \to A$		$B \to Syx$
$F \to Bx$	$S \to \varepsilon$		

$S' \to F'$	$F' \to Bx$	$A \to F'xy$	$B \to F'$
$S' \to Ay$	$F' \to A$		$B \to F'yx$
$S' \to Bx$	$F' \to \varepsilon$		

Task 16

- Remove all useless symbols from the given grammar.

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

Task 16

- Remove all useless symbols from the given grammar.

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

Procedure for removing useless symbols:

Task 16

- Remove all useless symbols from the given grammar.

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

Procedure for removing useless symbols:

a) Remove dead symbols

Task 16

- Remove all useless symbols from the given grammar.

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

Procedure for removing useless symbols:

a) Remove dead symbols
b) Remove unreachable symbols

Task 16

a) Removing dead symbols

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: {

Task 16

a) Removing dead symbols

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

List of alive symbols: {

a) We add terminal symbols to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e,

a) We add terminal symbols to the list of alive symbols

Task 16

a) Removing dead symbols

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

List of alive symbols: { a, b, c, d, e,

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e,

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E

a) We add terminal symbols to the list of alive symbols

b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E

a) We add terminal symbols to the list of alive symbols

b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C

a) We add terminal symbols to the list of alive symbols

b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C, B

a) We add terminal symbols to the list of alive symbols

b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C, B

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols

Task 16

a) Removing dead symbols

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols
c) Repeat step b) until there are no changes to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols
c) Repeat step b) until there are no changes to the list of alive symbols

Task 16

a) Removing dead symbols

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols
c) Repeat step b) until there are no changes to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols
c) Repeat step b) until there are no changes to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A, S }

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols
c) Repeat step b) until there are no changes to the list of alive symbols

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A, S }

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols
c) Repeat step b) until there are no changes to the list of alive symbols

List of dead symbols: { D }

Task 16

a) Removing dead symbols

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A, S }

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols
c) Repeat step b) until there are no changes to the list of alive symbols

List of dead symbols: { D }

Remove **ALL** production rules that contain dead symbols.

Task 16

a) Removing dead symbols

$S \to bAbE$		
$S \to aABc$	$B \to ad$	
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of alive symbols: { a, b, c, d, e, E, C, B, A, S }

a) We add terminal symbols to the list of alive symbols
b) If the right side of the production rule consist only of alive symbols, add left side of the production to the list of alive symbols
c) Repeat step b) until there are no changes to the list of alive symbols

List of dead symbols: { D }

Remove **ALL** production rules that contain dead symbols.

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: {

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: {

a) Put starting non-terminal symbol into list of reachable states

Task 16

b) Removing unreachable states

$S \rightarrow bAbE$	$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$
$S \rightarrow aABc$	$B \rightarrow ad$	$E \rightarrow ed$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ac$

List of reachable states: { S,

a) Put starting non-terminal symbol into list of reachable states

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: { S,

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: { S,

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states
c) Repeat step b) until there are no changes to the list of reachable symbols

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: { S,

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states
c) Repeat step b) until there are no changes to the list of reachable symbols

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: { S, a, b, c, A, B, E

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states
c) Repeat step b) until there are no changes to the list of reachable symbols

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: { S, a, b, c, A, B, E

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states
c) Repeat step b) until there are no changes to the list of reachable symbols

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: { S, a, b, c, A, B, E, d, e }

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states
c) Repeat step b) until there are no changes to the list of reachable symbols

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: { S, a, b, c, A, B, E, d, e }

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states
c) Repeat step b) until there are no changes to the list of reachable symbols

List of unreachable symbols: { C }

Task 16

b) Removing unreachable states

$S \to bAbE$	$A \to \varepsilon$	$C \to \varepsilon$
$S \to aABc$	$B \to ad$	$E \to ed$
$A \to beA$	$C \to eA$	$E \to ac$

List of reachable states: { S, a, b, c, A, B, E, d, e }

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states
c) Repeat step b) until there are no changes to the list of reachable symbols

List of unreachable symbols: { C }

Remove **ALL** productions that contain unreachable states.

Task 16

b) Removing unreachable states

$S \rightarrow bAbE$	$A \rightarrow \varepsilon$	
$S \rightarrow aABc$	$B \rightarrow ad$	$E \rightarrow ed$
$A \rightarrow beA$		$E \rightarrow ac$

List of reachable states: { S, a, b, c, A, B, E, d, e }

a) Put starting non-terminal symbol into list of reachable states
b) If the left side of the production rule is in list of reachable states, add right side of the production rule to the list of reachable states
c) Repeat step b) until there are no changes to the list of reachable symbols

List of unreachable symbols: { C }

Remove **ALL** productions that contain unreachable states.

Task 16

- What if we first tried to remove unreachable symbols?:

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

Task 16

- What if we first tried to remove unreachable symbols?:

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of reachable symbols: { S, b, A, E, a, B, c, e, D, C, d }

Task 16

- What if we first tried to remove unreachable symbols?:

$S \rightarrow bAbE$	$B \rightarrow DC$	$D \rightarrow cDAaB$
$S \rightarrow aABc$	$B \rightarrow ad$	$D \rightarrow bDaE$
$A \rightarrow beA$	$C \rightarrow eA$	$E \rightarrow ed$
$A \rightarrow \varepsilon$	$C \rightarrow \varepsilon$	$E \rightarrow ac$

List of reachable symbols: { S, b, A, E, a, B, c, e, D, C, d }

There are no unreachable symbols

Task 16

- What if we first tried to remove unreachable symbols?:

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of reachable symbols: { S, b, A, E, a, B, c, e, D, C, d }

There are no unreachable symbols

List of alive symbols: { E, C, B, A, S }

Task 16

- What if we first tried to remove unreachable symbols?:

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of reachable symbols: { S, b, A, E, a, B, c, e, D, C, d }

There are no unreachable symbols

List of alive symbols: { E, C, B, A, S }

D is a dead symbol

Task 16

- What if we first tried to remove unreachable symbols?:

$S \to bAbE$	$B \to DC$	$D \to cDAaB$
$S \to aABc$	$B \to ad$	$D \to bDaE$
$A \to beA$	$C \to eA$	$E \to ed$
$A \to \varepsilon$	$C \to \varepsilon$	$E \to ac$

List of reachable symbols: { S, b, A, E, a, B, c, e, D, C, d }

There are no unreachable symbols

List of alive symbols: { E, C, B, A, S }

D is a dead symbol

Symbol C remained in grammar but it is unreachable!

Task 17

- From the given grammar remove unit and ε productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$
	$A \to BC$	$B \to \varepsilon$	$C \to D$	$D \to \varepsilon$

Task 17

- From the given grammar remove unit and ε productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$
	$A \to BC$	$B \to \varepsilon$	$C \to D$	$D \to \varepsilon$

We iteratively remove unit and then ε productions, because by removing ε productions we might create new unit productions.

Task 17

a) Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$
	$A \to BC$	$B \to \varepsilon$	$C \to D$	$D \to \varepsilon$

Task 17

a) Removing unit productions.

$S \to xABz$ $A \to zyA$ $B \to wC$ $C \to zxC$ $D \to yB$

$A \to BC$ $B \to \varepsilon$ $C \to D$ $D \to \varepsilon$

We remove production rule: $C \to D$

Task 17

a) Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$
	$A \to BC$	$B \to \varepsilon$	$C \to D$	$D \to \varepsilon$

We remove production rule: $C \to D$

Task 17

a) Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$
	$A \to BC$	$B \to \varepsilon$	$C \to D$	$D \to \varepsilon$

We remove production rule: $C \to D$

We substitute non-terminal symbol D on the right side of the production rule with all right sides of the production rules that have D on their left side

Task 17

a) Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$
	$A \to BC$	$B \to \varepsilon$	$C \to D$	$D \to \varepsilon$

We remove production rule: $C \to D$

We substitute non-terminal symbol D on the right side of the production rule with all right sides of the production rules that have D on their left side

Task 17

a) Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$	$C \to D$	$D \to \varepsilon$	$C \to \varepsilon$

We remove production rule: $C \to D$

We substitute non-terminal symbol D on the right side of the production rule with all right sides of the production rules that have D on their left side

Task 17

a) Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$D \to \varepsilon$	$C \to \varepsilon$

We remove production rule: $C \to D$

We substitute non-terminal symbol D on the right side of the production rule with all right sides of the production rules that have D on their left side

Task 17

a) Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$D \to \varepsilon$	$C \to \varepsilon$

We remove production rule: $C \to D$

We substitute non-terminal symbol D on the right side of the production rule with all right sides of the production rules that have D on their left side

Task 17

a) Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$D \to yB$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$D \to \varepsilon$	$C \to \varepsilon$

We remove production rule: $C \to D$

We substitute non-terminal symbol D on the right side of the production rule with all right sides of the production rules that have D on their left side

Non-terminal symbol D has become unreachable so we remove all productions that contain it.

Task 17

a) Removing unit productions.

$S \to xABz$ $A \to zyA$ $B \to wC$ $C \to zxC$ $C \to yB$

$A \to BC$ $B \to \varepsilon$ $C \to \varepsilon$

We remove production rule: $C \to D$

We substitute non-terminal symbol D on the right side of the production rule with all right sides of the production rules that have D on their left side

Non-terminal symbol D has become unreachable so we remove all productions that contain it.

Task 17

b) Removing ε productions.

$S \to xABz$ $A \to zyA$ $B \to wC$ $C \to zxC$ $C \to yB$

$A \to BC$ $B \to \varepsilon$ $C \to \varepsilon$

Task 17

b) Removing ε productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Task 17

b) Removing ε productions.

$S \to xABz$ $A \to zyA$ $B \to wC$ $C \to zxC$ $C \to yB$

$A \to BC$ $B \to \varepsilon$ $C \to \varepsilon$

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Task 17

b) Removing ε productions.

$S \rightarrow xABz$	$A \rightarrow zyA$	$B \rightarrow wC$	$C \rightarrow zxC$	$C \rightarrow yB$
	$A \rightarrow BC$	$B \rightarrow \varepsilon$		$C \rightarrow \varepsilon$

Productions to be removed: $B \rightarrow \varepsilon$, $C \rightarrow \varepsilon$, $A \rightarrow BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

$S \to xABz$ $A \to zyA$ $B \to wC$ $C \to zxC$ $C \to yB$

$A \to BC$ $B \to \varepsilon$ $C \to \varepsilon$

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$

$S \to xABz$

$S \to xAz$

$S \to xBz$

$S \to xz$

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with ***2^n^*** new production rules.

Task 17

b) Removing ε productions.

$A \to zyA$	$B \to wC$	$C \to zxC$	$C \to yB$
$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$

$S \to xABz$

$S \to xAz$

$S \to xBz$

$S \to xz$

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

$A \rightarrow zyA$	$B \rightarrow wC$	$C \rightarrow zxC$	$C \rightarrow yB$
$A \rightarrow BC$	$B \rightarrow \varepsilon$		$C \rightarrow \varepsilon$

$S \rightarrow xABz$

$S \rightarrow xAz$

$S \rightarrow xBz$

$S \rightarrow xz$

Productions to be removed: $B \rightarrow \varepsilon$, $C \rightarrow \varepsilon$, $A \rightarrow BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

	$A \to zyA$	$B \to wC$	$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$			
$S \to xAz$	$A \to zy$			
$S \to xBz$				
$S \to xz$				

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with ***2^n*** new production rules.

Task 17

b) Removing ε productions.

		$B \to wC$	$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$			
$S \to xAz$	$A \to zy$			
$S \to xBz$				
$S \to xz$				

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with ***2***^{n} new production rules.

Task 17

b) Removing ε productions.

		$B \to wC$	$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$			
$S \to xAz$	$A \to zy$			
$S \to xBz$				
$S \to xz$				

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with ***2^n*** new production rules.

Task 17

b) Removing ε productions.

		$B \to wC$	$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$			
$S \to xAz$	$A \to zy$			
$S \to xBz$	$A \to BC$			
$S \to xz$	$A \to B$			
	$A \to C$			

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

		$B \rightarrow wC$	$C \rightarrow zxC$	$C \rightarrow yB$
	$A \rightarrow BC$	$B \rightarrow \varepsilon$		$C \rightarrow \varepsilon$
$S \rightarrow xABz$	$A \rightarrow zyA$			
$S \rightarrow xAz$	$A \rightarrow zy$			
$S \rightarrow xBz$	$A \rightarrow BC$			
$S \rightarrow xz$	$A \rightarrow B$			
	$A \rightarrow C$			

Productions to be removed: $B \rightarrow \varepsilon$, $C \rightarrow \varepsilon$, $A \rightarrow BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with ***2^n*** new production rules.

Task 17

b) Removing ε productions.

		$B \to wC$	$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$	$B \to wC$		
$S \to xAz$	$A \to zy$	$B \to w$		
$S \to xBz$	$A \to BC$			
$S \to xz$	$A \to B$			
	$A \to C$			

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

			$C \rightarrow zxC$	$C \rightarrow yB$
	$A \rightarrow BC$	$B \rightarrow \varepsilon$		$C \rightarrow \varepsilon$
$S \rightarrow xABz$	$A \rightarrow zyA$	$B \rightarrow wC$		
$S \rightarrow xAz$	$A \rightarrow zy$	$B \rightarrow w$		
$S \rightarrow xBz$	$A \rightarrow BC$			
$S \rightarrow xz$	$A \rightarrow B$			
	$A \rightarrow C$			

Productions to be removed: $B \rightarrow \varepsilon$, $C \rightarrow \varepsilon$, $A \rightarrow BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

			$C\to zxC$	$C\to yB$
	$A\to BC$	$B\to\varepsilon$		$C\to\varepsilon$
$S\to xABz$	$A\to zyA$	$B\to wC$		
$S\to xAz$	$A\to zy$	$B\to w$		
$S\to xBz$	$A\to BC$			
$S\to xz$	$A\to B$			
	$A\to C$			

Productions to be removed: $B\to\varepsilon$, $C\to\varepsilon$, $A\to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

			$C \to zxC$	$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	
$S \to xBz$	$A \to BC$			
$S \to xz$	$A \to B$			
	$A \to C$			

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with ***2^n*** new production rules.

Task 17

b) Removing ε productions.

				$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	
$S \to xBz$	$A \to BC$			
$S \to xz$	$A \to B$			
	$A \to C$			

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

				$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	
$S \to xBz$	$A \to BC$			
$S \to xz$	$A \to B$			
	$A \to C$			

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

b) Removing ε productions.

				$C \to yB$
	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$C \to yB$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$C \to y$
$S \to xBz$	$A \to BC$			
$S \to xz$	$A \to B$			
	$A \to C$			

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with ***2^n*** new production rules.

Task 17

b) Removing ε productions.

	$A \to BC$	$B \to \varepsilon$		$C \to \varepsilon$
$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$C \to yB$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$C \to y$
$S \to xBz$	$A \to BC$			
$S \to xz$	$A \to B$			
	$A \to C$			

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with ***2^n*** new production rules.

Task 17

b) Removing ε productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$C \to yB$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$C \to y$
$S \to xBz$	$A \to BC$			
$S \to xz$	$A \to B$			
	$A \to C$			

Productions to be removed: $B \to \varepsilon$, $C \to \varepsilon$, $A \to BC$

Empty symbols: { B, C, A }

Each production that contains ***n*** empty symbols we replace with $\boldsymbol{2^n}$ new production rules.

Task 17

- Removing unit productions.

$S \rightarrow xABz$	$A \rightarrow zyA$	$B \rightarrow wC$	$C \rightarrow zxC$
$S \rightarrow xAz$	$A \rightarrow zy$	$B \rightarrow w$	$C \rightarrow zx$
$S \rightarrow xBz$	$A \rightarrow BC$		$C \rightarrow yB$
$S \rightarrow xz$	$A \rightarrow B$		$C \rightarrow y$
	$A \rightarrow C$		

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$
$S \to xBz$	$A \to BC$		$C \to yB$
$S \to xz$	$A \to B$		$C \to y$
	$A \to C$		

We remove production rules: $A \to B$, $A \to C$

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$
$S \to xBz$	$A \to BC$		$C \to yB$
$S \to xz$	$A \to B$		$C \to y$
	$A \to C$		

We remove production rules: $A \to B$, $A \to C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$
$S \to xBz$	$A \to BC$		$C \to yB$
$S \to xz$	$A \to B$		$C \to y$
	$A \to C$		

We remove production rules: $A \to B$, $A \to C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \rightarrow xABz$	$A \rightarrow zyA$	$B \rightarrow wC$	$C \rightarrow zxC$
$S \rightarrow xAz$	$A \rightarrow zy$	$B \rightarrow w$	$C \rightarrow zx$
$S \rightarrow xBz$	$A \rightarrow BC$		$C \rightarrow yB$
$S \rightarrow xz$	$A \rightarrow B$		$C \rightarrow y$
	$A \rightarrow C$		

We remove production rules: $A \rightarrow B$, $A \rightarrow C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$A \to wC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$A \to w$
$S \to xBz$	$A \to BC$		$C \to yB$	
$S \to xz$	$A \to B$		$C \to y$	
	$A \to C$			

We remove production rules: $A \to B$, $A \to C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \rightarrow xABz$	$A \rightarrow zyA$	$B \rightarrow wC$	$C \rightarrow zxC$	$A \rightarrow wC$
$S \rightarrow xAz$	$A \rightarrow zy$	$B \rightarrow w$	$C \rightarrow zx$	$A \rightarrow w$
$S \rightarrow xBz$	$A \rightarrow BC$		$C \rightarrow yB$	
$S \rightarrow xz$			$C \rightarrow y$	
	$A \rightarrow C$			

We remove production rules: $A \rightarrow B$, $A \rightarrow C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$A \to wC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$A \to w$
$S \to xBz$	$A \to BC$		$C \to yB$	
$S \to xz$			$C \to y$	
	$A \to C$			

We remove production rules: $A \to B$, $A \to C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$A \to wC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$A \to w$
$S \to xBz$	$A \to BC$		$C \to yB$	
$S \to xz$			$C \to y$	
	$A \to C$			

We remove production rules: $A \to B$, $A \to C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$A \to wC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$A \to w$
$S \to xBz$	$A \to BC$		$C \to yB$	
$S \to xz$			$C \to y$	
	$A \to C$			

We remove production rules: $A \to B$, $A \to C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$A \to wC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$A \to w$
$S \to xBz$	$A \to BC$		$C \to yB$	$A \to zxC$
$S \to xz$			$C \to y$	$A \to zx$
	$A \to C$			$A \to yB$
				$A \to y$

We remove production rules: $A \to B$, $A \to C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \to xABz$	$A \to zyA$	$B \to wC$	$C \to zxC$	$A \to wC$
$S \to xAz$	$A \to zy$	$B \to w$	$C \to zx$	$A \to w$
$S \to xBz$	$A \to BC$		$C \to yB$	$A \to zxC$
$S \to xz$			$C \to y$	$A \to zx$
				$A \to yB$
				$A \to y$

We remove production rules: $A \to B$, $A \to C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 17

- Removing unit productions.

$S \rightarrow xABz$	$A \rightarrow zyA$	$B \rightarrow wC$	$C \rightarrow zxC$	$A \rightarrow wC$
$S \rightarrow xAz$	$A \rightarrow zy$	$B \rightarrow w$	$C \rightarrow zx$	$A \rightarrow w$
$S \rightarrow xBz$	$A \rightarrow BC$		$C \rightarrow yB$	$A \rightarrow zxC$
$S \rightarrow xz$			$C \rightarrow y$	$A \rightarrow zx$
				$A \rightarrow yB$
				$A \rightarrow y$

We remove production rules: $A \rightarrow B$, $A \rightarrow C$

We substitute non-terminal symbol B on the right side of the production rule with all right sides of the production rules that have B on their left side

We substitute non-terminal symbol C on the right side of the production rule with all right sides of the production rules that have C on their left side

Task 18

- Convert given grammar to Chomsky grammar.

$S \rightarrow 0S1$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$
$S \rightarrow 0SBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow A$
$S \rightarrow 1C0$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow \varepsilon$

Task 18

- Convert given grammar to Chomsky grammar.

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to A$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to \varepsilon$

Chomsky grammar production rules shape: $\boldsymbol{A \to BC}$ or $\boldsymbol{A \to d}$

Task 18

- Convert given grammar to Chomsky grammar.

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to A$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to \varepsilon$

Chomsky grammar production rules shape: ***A→BC*** or ***A→d***

Algorithm for converting to Chomsky grammar:

Task 18

- Convert given grammar to Chomsky grammar.

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to A$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to \varepsilon$

Chomsky grammar production rules shape: ***A→BC*** or ***A→d***

Algorithm for converting to Chomsky grammar:

a) Remove unit and ε productions

Task 18

- Convert given grammar to Chomsky grammar.

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to A$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to \varepsilon$

Chomsky grammar production rules shape: $\boldsymbol{A \to BC}$ or $\boldsymbol{A \to d}$

Algorithm for converting to Chomsky grammar:

a) Remove unit and ε productions

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

Task 18

- Convert given grammar to Chomsky grammar.

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to A$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to \varepsilon$

Chomsky grammar production rules shape: $\boldsymbol{A \to BC}$ or $\boldsymbol{A \to d}$

Algorithm for converting to Chomsky grammar:

a) Remove unit and ε productions

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

c) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

Task 18

a) Remove unit and ε productions

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to A$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to \varepsilon$

Task 18

a) Remove unit and ε productions

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to A$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to \varepsilon$

We remove production rules: $C \to A$, $C \to \varepsilon$

Task 18

a) Remove unit and ε productions

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to A$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to \varepsilon$

We remove production rules: $C \to A$, $C \to \varepsilon$

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to 1B0$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to SB$
$S \to 10$			$C \to 0$

Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to 1B0$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to SB$
$S \to 10$			$C \to 0$

Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \rightarrow 0S1$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$
$S \rightarrow 0SBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$
$S \rightarrow 1C0$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$
$S \rightarrow 10$			$C \rightarrow 0$

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

Terminal symbol “1” is replaced by non-terminal symbol ***J***.

Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \rightarrow 0S1$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$	$N \rightarrow 0$
$S \rightarrow 0SBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow 1C0$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow 10$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

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$S \rightarrow 0S1$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$	$N \rightarrow 0$
$S \rightarrow 0SBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow 1C0$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow 10$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

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$S \to 0S1$	$A \to 1B0$	$B \to 1BA$	$C \to B0$	$N \to 0$
$S \to 0SBS$	$A \to SB$	$B \to SA$	$C \to 1B0$	$J \to 1$
$S \to 1C0$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to 10$			$C \to 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

Terminal symbol “1” is replaced by non-terminal symbol ***J***.

Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \rightarrow NSJ$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$	$N \rightarrow 0$
$S \rightarrow 0SBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow 1C0$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow 10$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

Terminal symbol “1” is replaced by non-terminal symbol ***J***.

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$S \rightarrow NSJ$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$	$N \rightarrow 0$
$S \rightarrow 0SBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow 1C0$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow 10$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

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$S \rightarrow NSJ$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow 1C0$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow 10$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

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$S \rightarrow NSJ$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow 1C0$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow 10$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

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$S \rightarrow NSJ$	$A \rightarrow 1B0$	$B \rightarrow 1BA$	$C \rightarrow B0$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow 10$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

Terminal symbol “1” is replaced by non-terminal symbol ***J***.

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$S \to NSJ$	$A \to 1B0$	$B \to 1BA$	$C \to B0$	$N \to 0$
$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to 1B0$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
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$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

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$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

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$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
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$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
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$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to 1B0$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
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$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to 1B0$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
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$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

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$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
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$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

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$S \rightarrow NSJ$	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow B0$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

Terminal symbol “1” is replaced by non-terminal symbol ***J***.

Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \to NSJ$	$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to 1B0$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to JN$			$C \to 0$	

Terminal symbol "0" is replaced by non-terminal symbol ***N***.

Terminal symbol "1" is replaced by non-terminal symbol ***J***.

Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \rightarrow NSJ$	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow 1B0$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

Terminal symbol “1” is replaced by non-terminal symbol ***J***.

Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \rightarrow NSJ$	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

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$S \rightarrow NSJ$	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

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Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \to NSJ$	$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to JN$			$C \to 0$	

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Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \rightarrow NSJ$	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

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Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \to NSJ$	$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to JN$			$C \to 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

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Task 18

b) Terminal symbols that are present in production rules, which contain more than one symbol on the right side, are replaced with new non-terminal symbols

$S \rightarrow NSJ$	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

Terminal symbol “0” is replaced by non-terminal symbol ***N***.

Terminal symbol “1” is replaced by non-terminal symbol ***J***.

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

$S \rightarrow NSJ$	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

$S \rightarrow NSJ$	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
$S \rightarrow NSBS$	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

$S \to NSJ$	$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to JN$			$C \to 0$	
$S \to ND_1$				
$D_1 \to SJ$				

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

	$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to JN$			$C \to 0$	
$S \to ND_1$				
$D_1 \to SJ$				

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

	$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to JN$			$C \to 0$	
$S \to ND_1$				
$D_1 \to SJ$				

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

	$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$S \to NSBS$	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to JN$			$C \to 0$	
$S \to ND_1$				
$D_1 \to SJ$				
$S \to ND_2$				
$D_2 \to SD_3$				
$D_3 \to BS$				

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	
$S \rightarrow ND_1$				
$D_1 \rightarrow SJ$				
$S \rightarrow ND_2$				
$D_2 \rightarrow SD_3$				
$D_3 \rightarrow BS$				

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

	$A \rightarrow JBN$	$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
$S \rightarrow JCN$	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
$S \rightarrow JN$			$C \rightarrow 0$	
$S \rightarrow ND_1$				
$D_1 \rightarrow SJ$				
$S \rightarrow ND_2$				
$D_2 \rightarrow SD_3$				
$D_3 \rightarrow BS$				

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

	$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$S \to JCN$	$A \to 0$	$B \to 1$	$C \to SB$	
$S \to JN$			$C \to 0$	
$S \to ND_1$				
$D_1 \to SJ$				
$S \to ND_2$				
$D_2 \to SD_3$	$S \to JD_4$			
$D_3 \to BS$	$D_4 \to CN$			

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

$A \to JBN$ $\quad B \to JBA$ $\quad C \to BN$ $\quad N \to 0$

$A \to SB$ $\quad B \to SA$ $\quad C \to JBN$ $\quad J \to 1$

$A \to 0$ $\quad B \to 1$ $\quad C \to SB$

$C \to 0$

$S \to JN$

$S \to ND_1$

$D_1 \to SJ$

$S \to ND_2$

$D_2 \to SD_3$ $\quad S \to JD_4$

$D_3 \to BS$ $\quad D_4 \to CN$

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$A \to 0$	$B \to 1$	$C \to SB$	
		$C \to 0$	

$S \to JN$

$S \to ND_1$

$D_1 \to SJ$

$S \to ND_2$

$D_2 \to SD_3$ $\quad S \to JD_4$

$D_3 \to BS$ $\quad D_4 \to CN$

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$A \to JBN$	$B \to JBA$	$C \to BN$	$N \to 0$
$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
$A \to 0$	$B \to 1$	$C \to SB$	
		$C \to 0$	

$S \to JN$	
$S \to ND_1$	$A \to JD_5$
$D_1 \to SJ$	$D_5 \to BN$
$S \to ND_2$	
$D_2 \to SD_3$	$S \to JD_4$
$D_3 \to BS$	$D_4 \to CN$

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

$B \to JBA$ $C \to BN$ $N \to 0$

$A \to SB$ $B \to SA$ $C \to JBN$ $J \to 1$

$A \to 0$ $B \to 1$ $C \to SB$

$C \to 0$

$S \to JN$

$S \to ND_1$ $A \to JD_5$

$D_1 \to SJ$ $D_5 \to BN$

$S \to ND_2$

$D_2 \to SD_3$ $S \to JD_4$

$D_3 \to BS$ $D_4 \to CN$

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

		$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
			$C \rightarrow 0$	

$S \rightarrow JN$

$S \rightarrow ND_1$ $\quad A \rightarrow JD_5$

$D_1 \rightarrow SJ$ $\quad D_5 \rightarrow BN$

$S \rightarrow ND_2$

$D_2 \rightarrow SD_3$ $\quad S \rightarrow JD_4$

$D_3 \rightarrow BS$ $\quad D_4 \rightarrow CN$

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

		$B \rightarrow JBA$	$C \rightarrow BN$	$N \rightarrow 0$
	$A \rightarrow SB$	$B \rightarrow SA$	$C \rightarrow JBN$	$J \rightarrow 1$
	$A \rightarrow 0$	$B \rightarrow 1$	$C \rightarrow SB$	
			$C \rightarrow 0$	
$S \rightarrow JN$				
$S \rightarrow ND_1$	$A \rightarrow JD_5$	$B \rightarrow JD_6$		
$D_1 \rightarrow SJ$	$D_5 \rightarrow BN$	$D_6 \rightarrow BA$		
$S \rightarrow ND_2$				
$D_2 \rightarrow SD_3$	$S \rightarrow JD_4$			
$D_3 \rightarrow BS$	$D_4 \rightarrow CN$			

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

			$C \to BN$	$N \to 0$
	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
	$A \to 0$	$B \to 1$	$C \to SB$	
			$C \to 0$	
$S \to JN$				
$S \to ND_1$	$A \to JD_5$	$B \to JD_6$		
$D_1 \to SJ$	$D_5 \to BN$	$D_6 \to BA$		
$S \to ND_2$				
$D_2 \to SD_3$	$S \to JD_4$			
$D_3 \to BS$	$D_4 \to CN$			

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

			$C \to BN$	$N \to 0$
	$A \to SB$	$B \to SA$	$C \to JBN$	$J \to 1$
	$A \to 0$	$B \to 1$	$C \to SB$	
			$C \to 0$	
$S \to JN$				
$S \to ND_1$	$A \to JD_5$	$B \to JD_6$		
$D_1 \to SJ$	$D_5 \to BN$	$D_6 \to BA$		
$S \to ND_2$				
$D_2 \to SD_3$	$S \to JD_4$			
$D_3 \to BS$	$D_4 \to CN$			

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

$C \to BN$ $N \to 0$

$A \to SB$ $B \to SA$ $C \to JBN$ $J \to 1$

$A \to 0$ $B \to 1$ $C \to SB$

$C \to 0$

$S \to JN$

$S \to ND_1$ $A \to JD_5$ $B \to JD_6$ $C \to JD_5$

$D_1 \to SJ$ $D_5 \to BN$ $D_6 \to BA$

$S \to ND_2$

$D_2 \to SD_3$ $S \to JD_4$

$D_3 \to BS$ $D_4 \to CN$

Task 18

a) Production rules that have more than two symbols on the right side are broken into sub-productions with two symbols on the right side

$C \rightarrow BN$ $N \rightarrow 0$

$A \rightarrow SB$ $B \rightarrow SA$ $J \rightarrow 1$

$A \rightarrow 0$ $B \rightarrow 1$ $C \rightarrow SB$

$S \rightarrow JN$ $C \rightarrow 0$

$S \rightarrow ND_1$ $A \rightarrow JD_5$ $B \rightarrow JD_6$ $C \rightarrow JD_5$

$D_1 \rightarrow SJ$ $D_5 \rightarrow BN$ $D_6 \rightarrow BA$

$S \rightarrow ND_2$

$D_2 \rightarrow SD_3$ $S \rightarrow JD_4$

$D_3 \rightarrow BS$ $D_4 \rightarrow CN$

Task 19

- Show that the given grammar is ambiguous.

1) $S \rightarrow aSbS$
2) $S \rightarrow bSaS$
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We will show that the grammar is ambiguous by generating sequence '**abab**' in two different ways

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First way:

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$$S \xrightarrow{1} a\underline{S}bS$$

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First way:

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$$S$$

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Second way:

$$S \xrightarrow{1} a\underline{S}bS \xrightarrow{2} ab\underline{S}aSbS$$

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Second way:

$$S \xrightarrow{1} a\underline{S}bS \xrightarrow{2} ab\underline{S}aSbS \xrightarrow{3} aba\underline{S}bS \xrightarrow{3} abab\underline{S} \xrightarrow{3} abab$$