CD: COMPILER DESIGN
SPM: UNIT-1 20/09/2022

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PREPARED FOR

Engineering Students

All Engineering College

CD: COMPILER DESIGN

TOPIC On : UNIT-1 LEXICAL ANALYZER, lastpos, firstpos, followpos, syntax tree method DFA
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By SHWETA TIWARI

Under On: INTRODUCTION TO COMPILER

TOPIC On : UNIT–1 LEXICAL ANALYZER, lastpos, firstpos, followpos, syntax tree method DFA

Lexical Analyzer

- Conversion from regular expression to DFA

Converting Regular Expressions Directly to DFAs
Explanation with examples

Converting Regular Expressions Directly to DFAs

- We may convert a **regular expression into a DFA**
- (without creating a NFA first).

- First we augment the given regular expression by concatenating it with a special symbol #.
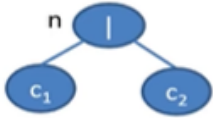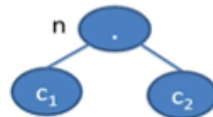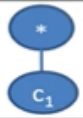
    r ➜ (r)#   augmented regular expression

Steps for Converting a RE Directly to a DFA

➤ Construct a syntax tree for (r)#

➤ Traverse the tree to construct functions *nullable, firstpos, lastpos,* and *followpos*

➤ Computing *followpos*

➤ Converting **a RE Directly to a DFA**

❏ Function computed from the syntax tree

- *nullable(n)*
  - The subtree at node n generates languages including the empty string.
- *firstpos(n)*
  - The set of positions that can match the first symbol of a string generated by the subtree at node n.
- *lastpos(n)*
  - The set of positions that can match the last symbol of a string generated be the subtree at node n.
- *followpos(i)*
  - The set of positions that can follow position i in the tree.

❑ Rules to compute nullable, firstpos, lastpos

Node n	nullable(n)	firstpos(n)	lastpos(n)
A leaf labeled by ε	true	Ø	Ø
A leaf with position i	false	$\{i\}$	$\{i\}$
n | with children c_1, c_2	nullable(c_1) or nullable(c_2)	firstpos(c_1) $\cup$ firstpos(c_2)	lastpos(c_1) $\cup$ lastpos(c_2)
n . with children c_1, c_2	nullable(c_1) and nullable(c_2)	if (nullable(c_1)) then firstpos(c_1) $\cup$ firstpos(c_2) else firstpos(c_1)	if (nullable(c_2)) then lastpos(c_1) $\cup$ lastpos(c_2) else lastpos(c_2)
n * with child c_1	true	firstpos(c_1)	lastpos(c_1)

❑ Rules to compute followpos

1. If n is **concatenation** node with left child c1 and right child c2 and i is a position in lastpos(c1), then all position in firstpos(c2) are in followpos(i)

2. If n is * node and i is position in lastpos(n), then all position in firstpos(n) are in followpos(i)

❑ Conversion from regular expression to DFA without constructing NFA
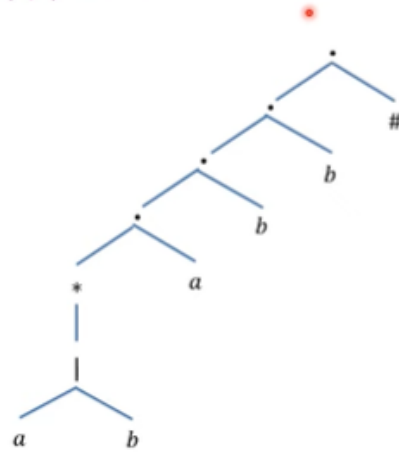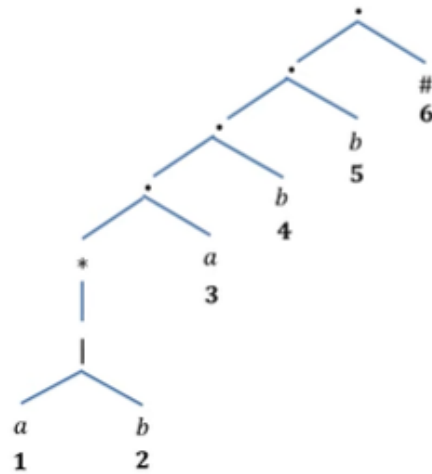
R.E: (a|b)*abb #

Step 1: Construct Syntax Tree

❏ Conversion from regular expression to DFA without constructing NFA

R.E: (a|b)*abb #

Step 1: Construct Syntax Tree

❏ Conversion from regular expression to DFA without constructing NFA

R.E: (a|b)*abb #

Step 1: Construct Syntax Tree

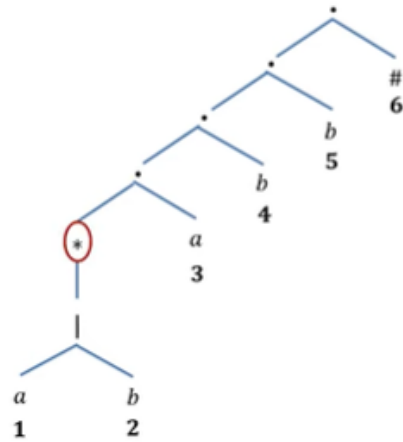## ❑ Conversion from regular expression to DFA without constructing NFA
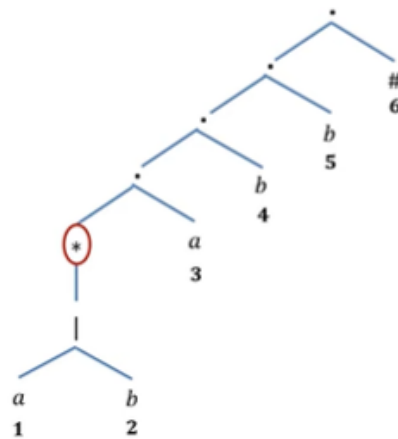
R.E: (a|b)*abb #

Step 1: Construct Syntax Tree

Step 2: Nullable node

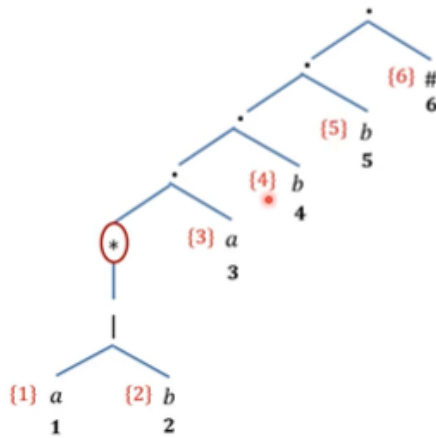## ❑ Conversion from regular expression to DFA without constructing NFA

Step 3: Calculate firstpos

❑ Conversion from regular expression to DFA without constructing NFA

Step 3: Calculate firstpos

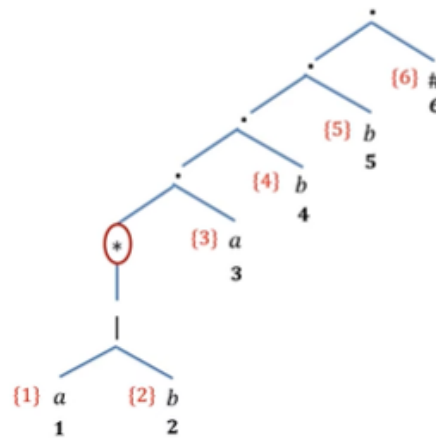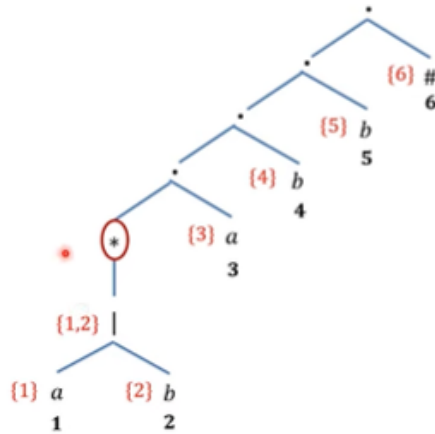A leaf with position $i = \{i\}$

❑ Conversion from regular expression to DFA without constructing NFA

Step 3: Calculate firstpos

A leaf with position $i = \{i\}$

n $firstpos(c_1) \cup firstpos(c_2)$

c_1 c_2

❑ Conversion from regular expression to DFA without constructing NFA

Step 3: Calculate firstpos

A leaf with position $i = \{i\}$

$$firstpos(c_1) \cup firstpos(c_2)$$

$$firstpos(c_1)$$

❑ Conversion from regular expression to DFA without constructing NFA

Step 3: Calculate firstpos

Firstpos ―

A leaf with position $i = \{i\}$

$$firstpos(c_1) \cup firstpos(c_2)$$

$$firstpos(c_1)$$

if $(nullable(c_1))$
$$firstpos(c_1) \cup firstpos(c_2)$$
else $firstpos(c_1)$

❑ Conversion from regular expression to DFA without constructing NFA

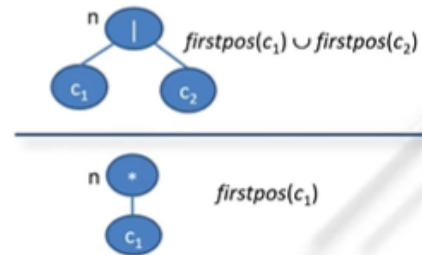Step 3: Calculate firstpos

A leaf with position $i = \{i\}$

$$firstpos(c_1) \cup firstpos(c_2)$$

$$firstpos(c_1)$$

if $(nullable(c_1))$
$firstpos(c_1) \cup firstpos(c_2)$
else $firstpos(c_1)$

Tree nodes (firstpos):
- $\{1,2,3\}$ · (root)
- $\{1,2,3\}$ ·
- $\{6\}$ # 6
- $\{1,2,3\}$ ·
- $\{5\}$ b 5
- $\{1,2,3\}$ ·
- $\{4\}$ b 4
- $\{1,2\}$ *
- $\{3\}$ a 3
- $\{1,2\}$ |
- $\{1\}$ a 1
- $\{2\}$ b 2

❑ Conversion from regular expression to DFA without constructing NFA

Step 3: Calculate lastpos

Tree nodes (lastpos):
- $\{1,2,3\}$ · (root)
- $\{1,2,3\}$ ·
- $\{6\}$ # 6
- $\{1,2,3\}$ ·
- $\{5\}$ b 5
- $\{1,2,3\}$ ·
- $\{4\}$ b 4
- $\{1,2\}$ *
- $\{3\}$ a 3
- $\{1,2\}$ |
- $\{1\}$ a 1
- $\{2\}$ b 2

❑ Conversion from regular expression to DFA without constructing NFA

Step 3: Calculate lastpos
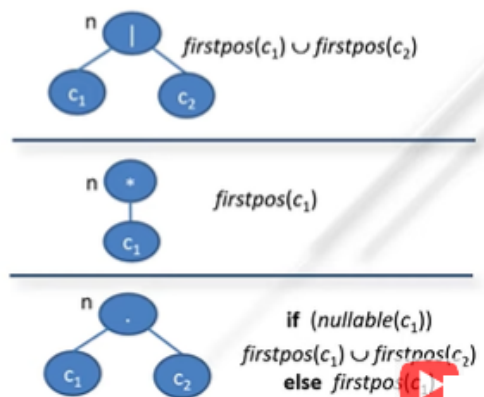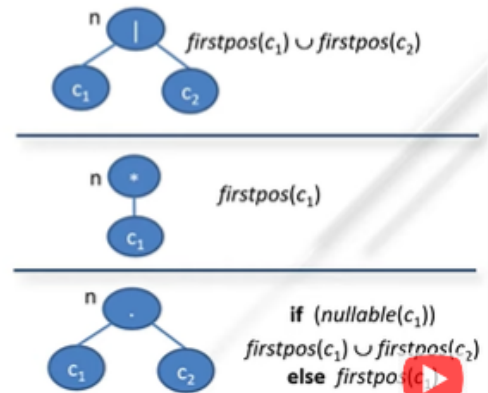

Lastpos —

A leaf with position $i = \{i\}$

$$lastpos(c_1) \cup lastpos(c_2)$$

$$lastpos(c_1)$$

if $(nullable(c_2))$
$lastpos(c_1) \cup lastpos(c_2)$
else $lastpos(c_2)$

❑ Conversion from regular expression to DFA without constructing NFA

Step 4: Calculate followpos

Firstpos —
Lastpos —

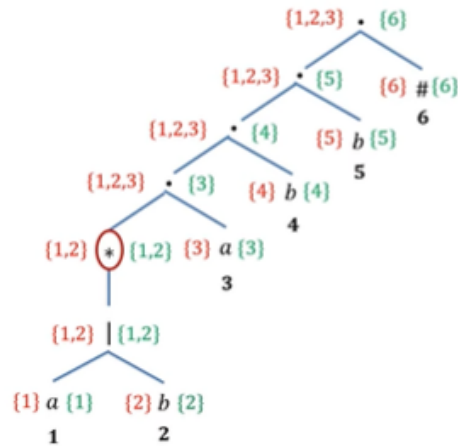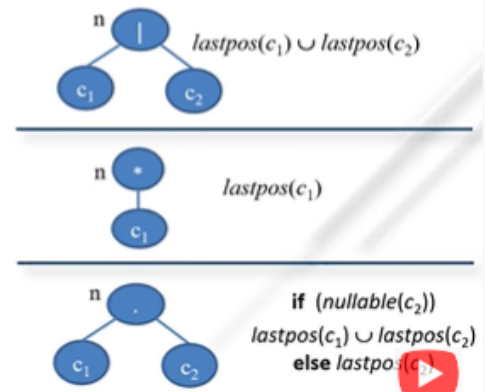## ❑ Conversion from regular expression to DFA without constructing NFA

Step 4: Calculate followpos

$$i = lastpos(c_1) = \{5\}$$
$$firstpos(c_2) = \{6\}$$

❑ Conversion from regular expression to DFA without constructing NFA
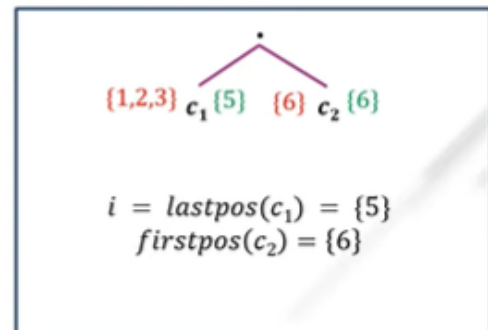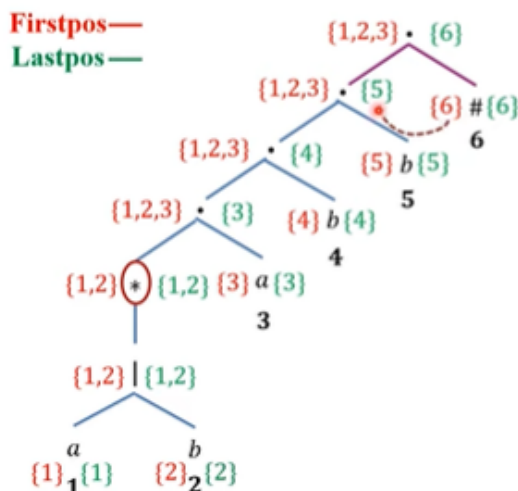
Step 4: Calculate followpos

Position	followpos
5	6
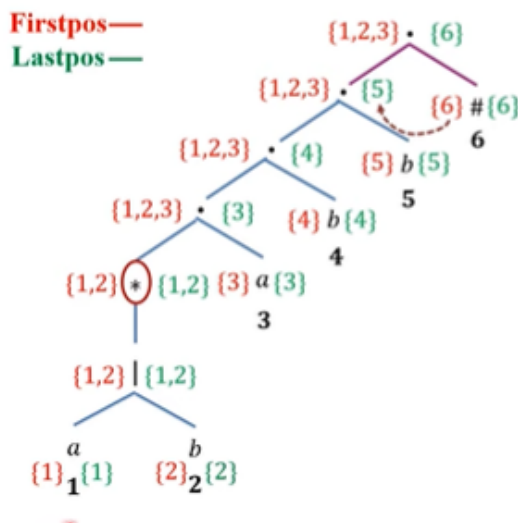
$$i = lastpos(c_1) = \{5\}$$
$$firstpos(c_2) = \{6\}$$
$$followpos(5) = \{6\}$$

❑ Conversion from regular expression to DFA without constructing NFA

Step 4: Calculate followpos

Firstpos—
Lastpos —

Position	followpos
5	6
4	5

$$i = lastpos(c_1) = \{4\}$$
$$firstpos(c_2) = \{5\}$$
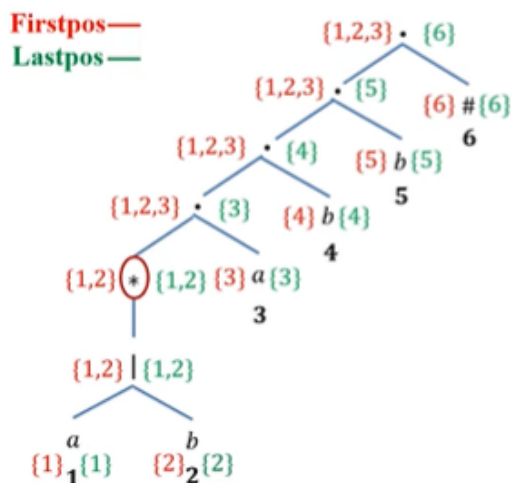$$followpos(4) = \{5\}$$

❑ Conversion from regular expression to DFA without constructing NFA

Step 4: Calculate followpos

Firstpos—
Lastpos —

Position	followpos
5	6
4	5
3	4

$$i = lastpos(c_1) = \{3\}$$
$$firstpos(c_2) = \{4\}$$
$$followpos(3) = \{4\}$$

❑ Conversion from regular expression to DFA without constructing NFA

Step 4: Calculate followpos

Position	followpos
5	6
4	5
3	4
2	3
1	3

$$i = lastpos(c_1) = \{1,2\}$$
$$firstpos(c_2) = \{3\}$$
$$followpos(1) = \{3\}$$
$$followpos(2) = \{3\}$$

❑ Conversion from regular expression to DFA without constructing NFA
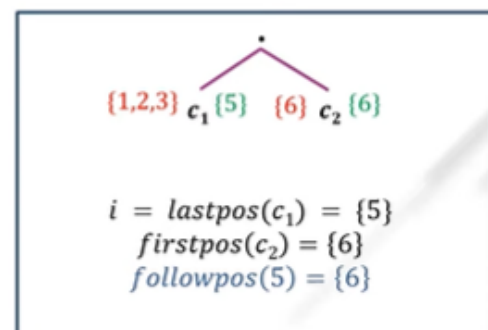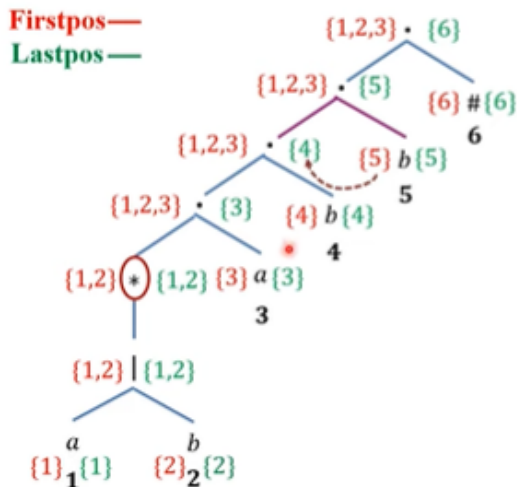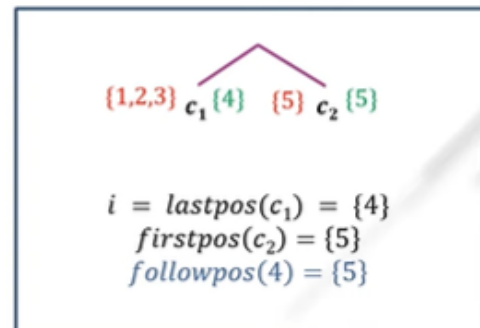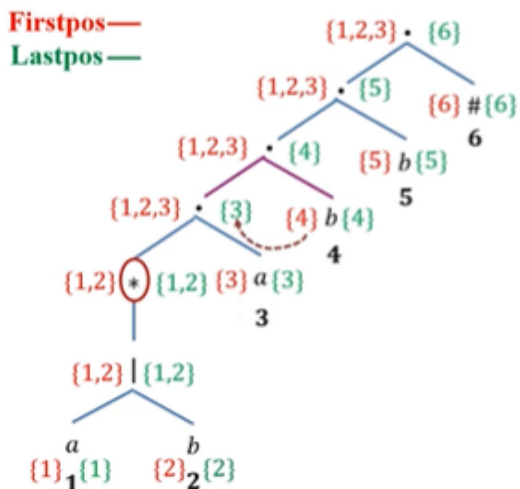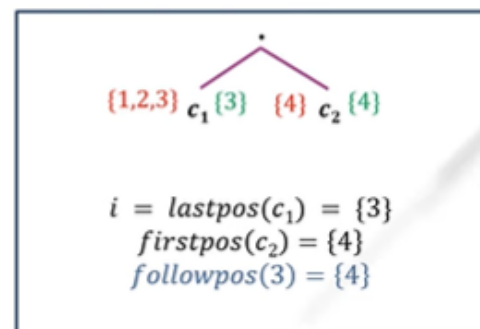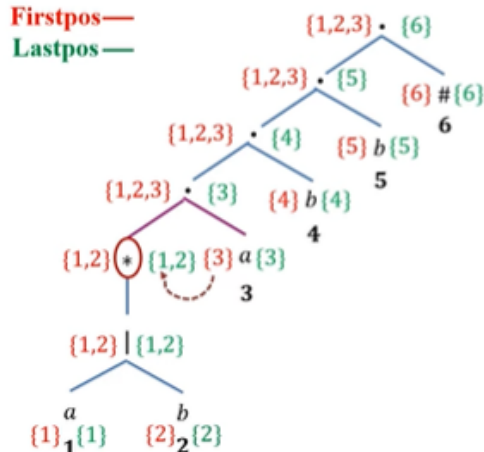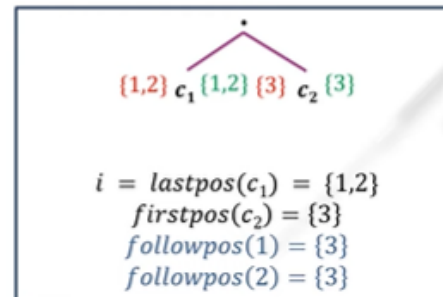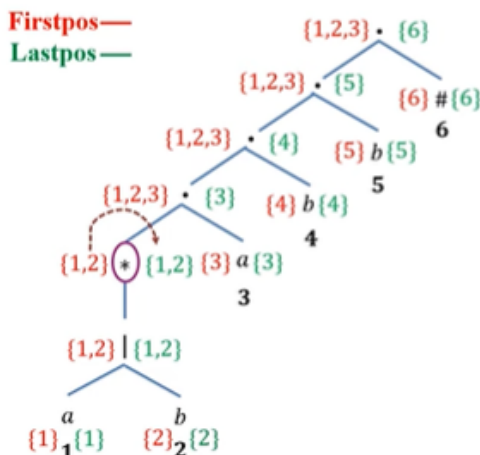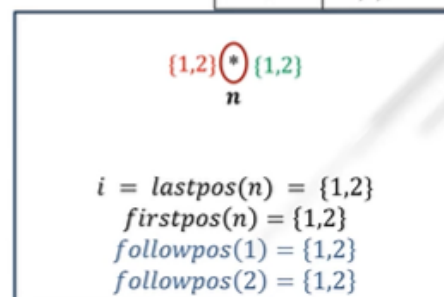
Step 4: Calculate followpos

Position	followpos
6	--
5	6
4	5
3	4
2	1,2,3
1	1,2,3

$$i = lastpos(n) = \{1,2\}$$
$$firstpos(n) = \{1,2\}$$
$$followpos(1) = \{1,2\}$$
$$followpos(2) = \{1,2\}$$

❑ Constructing DFA

```
                              {1,2,3}  ·  {6}
                         {1,2,3}  ·  {5}
                                        {6} # {6}
                                         6
                      {1,2,3}  ·  {4}   {5} b {5}
                                         5
                 {1,2,3}  ·  {3}   {4} b {4}
                                    4
            {1,2}  *  {1,2}  {3} a {3}
                   |             3
            {1,2}  | {1,2}
          {1} a {1}   {2} b {2}
           1           2
```

Position	followpos
6	--
5	6
4	5
3	4
2	1,2,3
1	1,2,3

❑ Constructing DFA

```
                              {1,2,3}  ·  {6}
                         {1,2,3}  ·  {5}
                                        {6} # {6}
                                         6
                      {1,2,3}  ·  {4}   {5} b {5}
                                         5
                 {1,2,3}  ·  {3}   {4} b {4}
                                    4
            {1,2}  *  {1,2}  {3} a {3}
                   |             3
            {1,2}  | {1,2}
          {1} a {1}   {2} b {2}
           1           2
```
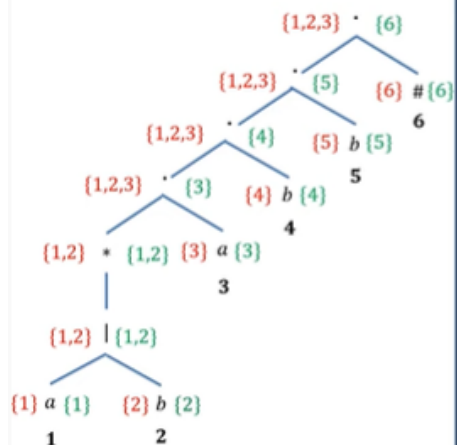
Initial state = $firstpos$ of root = {1,2,3} ----- A

State A

$\delta(\,(A,a) = followpos(1) \cup followpos(3)$

$\qquad = (1,2,3) \cup (4) = \{1,2,3,4\}$ ----- B

$\delta(\,(A,b) = followpos(2)$

$\qquad = (1,2,3)$ ----- A

Position	followpos
6	--
5	6
4	5
3	4
2	1,2,3
1	1,2,3

States	a	b
A={1,2,3}	B	A
B={1,2,3,4}		

❑ Constructing DFA

{1,2,3} · {6}

{1,2,3} · {5} {6} # {6}
6

{1,2,3} · {4} {5} b {5}
5

{1,2,3} · {3} {4} b {4}
4

{1,2} * {1,2} {3} a {3}
3

{1,2} | {1,2}

{1} a {1} {2} b {2}
1 2
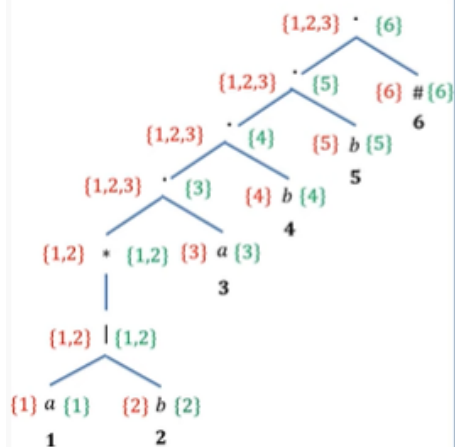
State B

$\delta(B,a) = followpos(1) \cup followpos(3)$

$= (1,2,3) \cup (4) = \{1,2,3,4\}$ ----- B

$\delta(B,b) = followpos(2) \cup followpos(4)$

$= (1,2,3) \cup (5) = \{1,2,3,5\}$ ----- C

Position	followpos
5	6
4	5
3	4
2	1,2,3
1	1,2,3

States	a	b
A={1,2,3}	B	A
B={1,2,3,4}	B	C
C={1,2,3,5}		

❑ Constructing DFA

{1,2,3} · {6}

{1,2,3} · {5} {6} # {6}
6

{1,2,3} · {4} {5} b {5}
5

{1,2,3} · {3} {4} b {4}
4

{1,2} * {1,2} {3} a {3}
3

{1,2} | {1,2}

{1} a {1} {2} b {2}
1 2
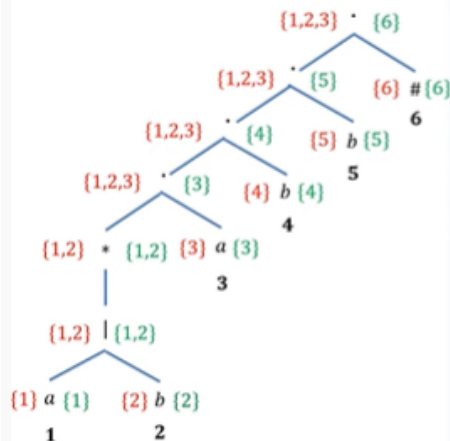
State B

$\delta(B,a) = followpos(1) \cup followpos(3)$

$= (1,2,3) \cup (4) = \{1,2,3,4\}$ ----- B

$\delta(B,b) = followpos(2) \cup followpos(4)$

$= (1,2,3) \cup (5) = \{1,2,3,5\}$ ----- C

State C

$\delta(C,a) = followpos(1) \cup followpos(3)$

$= (1,2,3) \cup (4) = \{1,2,3,4\}$ ----- B

$\delta(C,b) = followpos(2) \cup followpos(5)$

$= (1,2,3) \cup (6) = \{1,2,3,6\}$ ----- D

Position	followpos
5	6
4	5
3	4
2	1,2,3
1	1,2,3

States	a	b
A={1,2,3}	B	A
B={1,2,3,4}	B	C
C={1,2,3,5}	B	D
D={1,2,3,6}		

❑ Constructing DFA

```
                    {1,2,3} · {6}
                {1,2,3} · {5}    {6} # {6}
            {1,2,3} · {4}    {5} b {5}      6
        {1,2,3} · {3}    {4} b {4}      5
    {1,2} * {1,2} {3} a {3}         4
                              3
    {1,2} | {1,2}
{1} a {1}   {2} b {2}
    1           2
```

State D

$\delta(D,a)$ = followpos(1) U followpos(3)

$\quad$ =(1,2,3) U (4) = {1,2,3,4} ----- B

$\delta(D,b)$ = followpos(2)

$\quad$ =(1,2,3) ----- A

Position	followpos
6	--
5	{6}
4	{5}
3	{4}
2	{1,2,3}
1	{1,2,3}

States	a	b
A={1,2,3}	B	A
B={1,2,3,4}	B	C
C={1,2,3,5}	B	D
D={1,2,3,6}	B	A

Transition Table for DFA

❑ Constructing DFA

```
                    {1,2,3} · {6}
                {1,2,3} · {5}    {6} # {6}
            {1,2,3} · {4}    {5} b {5}      6
        {1,2,3} · {3}    {4} b {4}      5
    {1,2} * {1,2} {3} a {3}         4
                              3
    {1,2} | {1,2}
{1} a {1}   {2} b {2}
    1           2
```

State D

$\delta(D,a)$ = followpos(1) U followpos(3)

$\quad$ =(1,2,3) U (4) = {1,2,3,4} ----- B

$\delta(D,b)$ = followpos(2)

$\quad$ =(1,2,3) ----- A

Position	followpos
6	--
5	{6}
4	{5}
3	{4}
2	{1,2,3}
1	{1,2,3}

DFA for the R.E: (a|b)*abb

States	a	b
A={1,2,3}	B	A
B={1,2,3,4}	B	C
C={1,2,3,5}	B	D
D={1,2,3,6}	B	A

Transition Table for DFA

❏ Constructing DFA

Position	followpos
6	--
5	{6}
4	{5}
3	{4}
2	{1,2,3}
1	{1,2,3}

State D

$\delta(D,a)$ = followpos(1) U followpos(3)

$\quad$ =(1,2,3) U (4) = {1,2,3,4} ----- B
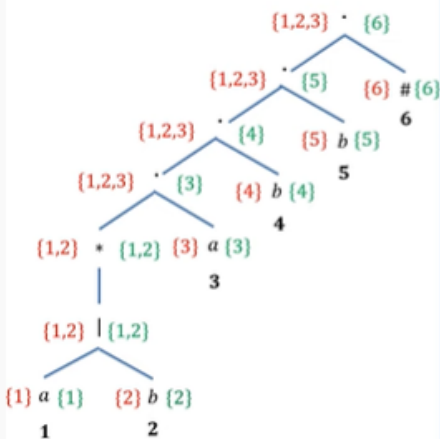
$\delta(D,b)$ = followpos(2)

$\quad$ =(1,2,3) ----- A

DFA for the R.E: (a|b)*abb
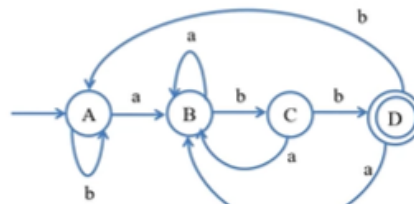
States	a	b
A={1,2,3}	B	A
B={1,2,3,4}	B	C
C={1,2,3,5}	B	D
D={1,2,3,6}	B	A

Transition Table for DFA

❏ Conversion from regular expression to DFA without constructing NFA

R.E: a*b*a(a | b)*b*a#

(Nov-2016) (7 marks)