



**DEPARTMENT OF CSE & IT**  
**23CS6401 / COMPILER DESIGN**  
**YEAR/ SEMESTER : III/VI**  
**UNIT I- INTRODUCTION TO COMPILER DESIGN**

**PART – B (16-Marks)**

**5. Apply Thompson's construction to convert the regular expression into its equivalent NFA with suitable state transitions. Illustrate regular expression to NFA for the sentence  $(a|b)^*a$**

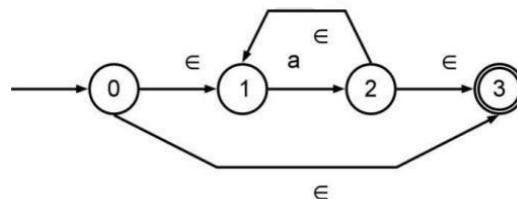
Construct the NFA from the  $(a/b)^*a$  using thompson's construction algorithm

Let us assume

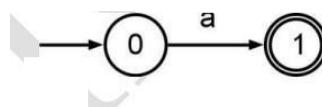
R1 =  $(a / b)$  and R2 = a

Thompson's Rules

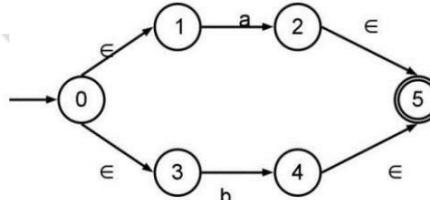
**Rule for  $a^*$**



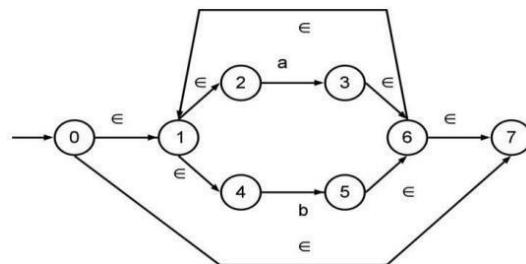
**Rule for a**



**Rule for  $a / b$**



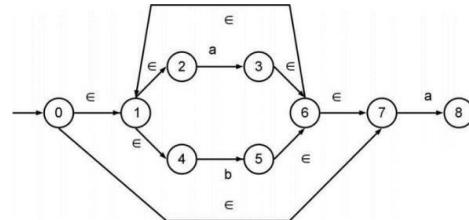
**R1:  $(a / b)^*$**



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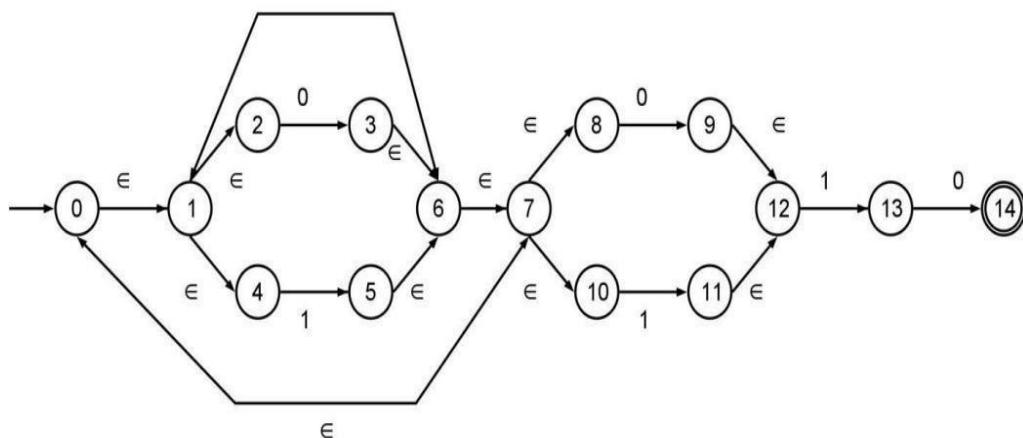


**R1 R2:(a / b)\* a**



**7. Apply DFA construction and minimization methods to derive the minimized DFA for the given regular expression  $(0+1)^*(0+1)$  10**

**(i) Construction of NFA**



**(ii) Find the DFA States**



$\in - \text{closure} (0) =$	$\{0,1,2,4,7,8,10\} = A$
$\text{Move}(A,0) =$	$\{3,9\}$
$\text{Move}(A,1) =$	$\{5,11\}$
$\in - \text{Closure of } (\text{Move}(A,0)) =$	$\{3,6,7,1,2,4,8,10,9,12\}$
$=$	$\{1,2,3,4,6,7,8,9,10,12\} = B$
$\in - \text{closure of } (\text{Move}(A,1)) =$	$\{5,6,7,8,10,1,2,4,11,12\}$
	$\{1,2,4,5,6,7,8,10,11,12\} = C$
$\text{Dtran}[A,0] =$	B
$\text{Dtran}[A,1] =$	C
$\text{Move}(B,0) =$	$\{3,9\}$
$\text{Move}(B,1) =$	$\{5,11,13\}$
$\in - \text{closure } (\text{Move}(B,0)) =$	$\{3,6,7,8,10,1,2,4,9,12\}$
	$\{1,2,3,4,6,7,8,9,10,12\} = B$
$\in - \text{closure } (\text{Move}(B,1)) =$	$\{1,2,4,5,6,7,8,10,11,12,13\} = D$
$\text{Dtran}[B,0] =$	B
$\text{Dtran}[B,1] =$	D
$\text{Move}(C,0) =$	$\{3,9\}$
$\text{Move}(C,1) =$	$\{5,11,13\}$
$\in - \text{closure } (\text{Move}(C,0)) =$	B
$\in - \text{closure } (\text{Move}(C,1)) =$	D
$\text{Dtran}[C,0] =$	B

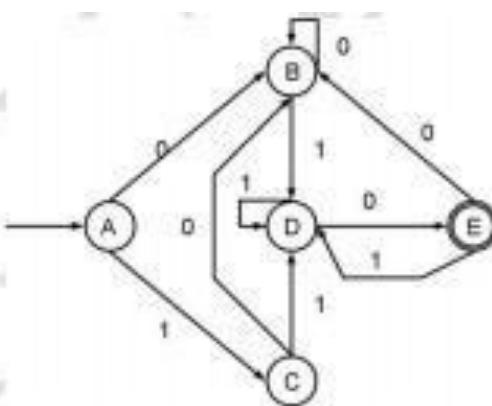


Dtran[C,1]=	D
Move(D,0)=	{3,9,14}
Move(D,1)=	{5,11,13}
$\epsilon$ -closure(Move(D,0))=	{3,6,7,8,10,1,2,4,9,12,14}
	{1,2,3,4,6,7,8,9,10,12,14}=E
$\epsilon$ -closure(Move(D,1))=	D
Dtran[D,0]=	E
Dtran[D,1]=	D
Move(E,0)=	{3,9}
Move(E,1)=	{5,11,13}
$\epsilon$ -closure(Move(E,0))=	B
$\epsilon$ -closure(Move(E,0))=	D
Dtran[E,0]=	B
Dtran[E,1}=	D

### (iii) Construction of Transition Table

States	i/p Symbols	
	0	1
->A	B	C
B	B	D
C	B	D
D	E	D
*E	B	D

### (iv) Construction of DFA



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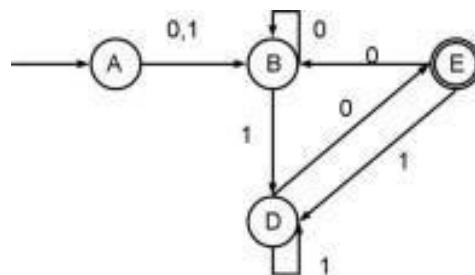
**(v) Minimization of DFA**

$$\begin{aligned} &= (ABCD)(E) \\ &= (ABC)(D)(E) \\ &= (A)(BC)(D)(E) \end{aligned}$$

**(vi) Minimized DTRAN**

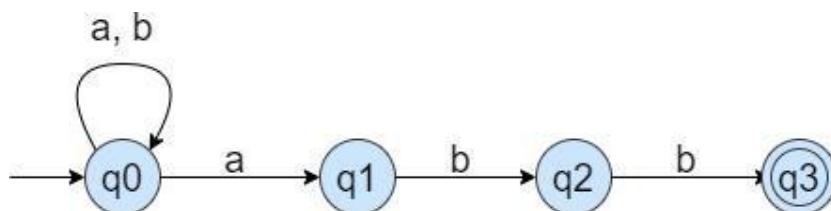
States	i/p Symbols	
	0	1
-> <b>A</b>	B	B
<b>B</b>	B	D
<b>D</b>	E	D
* <b>E</b>	B	D

**(vii) Minimized DFA**



**8. Apply the direct DFA construction method to convert the regular expression  $(a+b)^*abb$  into an equivalent DFA.**

The NFA of the regular expression  $(a+b)^*abb$  is given below.



**The transition table of the NFA is**

State	a	b
$\rightarrow\{q_0\}$	$\{q_0, q_1\}$	$\{q_0\}$
$\{q_1\}$	—	$\{q_2\}$

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{q2}	—	{q3}
*{q3}	—	—

Convert the above NFA to DFA by expanding the transition table. Start by adding new states to the transition table.

State	a	b
→{q0}	{q0, q1}	{q0}
{q1}	—	{q2}
{q2}	—	{q3}
*{q3}	—	—
{q0, q1}	{q0, q1}	{q0, q2}
{q0, q2}	{q0, q1}	{q0, q3}
*{q0, q3}	{q0, q1}	{q0}

q<sub>0</sub> is our start state. It is impossible to reach q<sub>1</sub>, q<sub>2</sub>, q<sub>3</sub> from q<sub>0</sub>. Remove q<sub>1</sub>, q<sub>2</sub>, q<sub>3</sub> from the transition table.

State	a	b
→{q0}	{q0, q1}	{q0}
{q0, q1}	{q0, q1}	{q0, q2}
{q0, q2}	{q0, q1}	{q0, q3}
*{q0, q3}	{q0, q1}	{q0}

Rename the states to make things simpler.

1. Replace {q0, q1} by {q1}
2. Replace {q0, q2} by {q2}
3. Replace {q0, q3} by {q3}

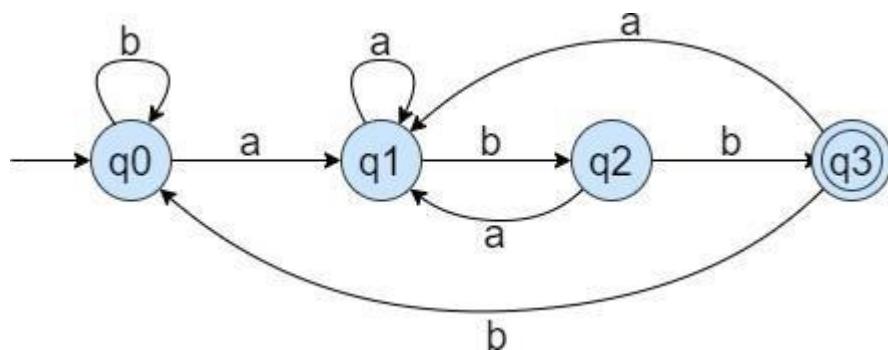
State	a	B
→{q0}	{q1}	{q0}

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{q1}	{q1}	{q2}
{q2}	{q1}	{q3}
*{q3}	{q1}	{q0}

The above transition table represents a deterministic automata. Construct DFA of  $(a+b)^*abb$  using above transition table.



### 11. Apply Thompson's construction algorithm to construct an NFA for the regular expression $(a/b)^*a(a/b)$

Construct the NFA from the  $(a/b)^*a(a/b)$  using thompson's construction algorithm  
Let us assume

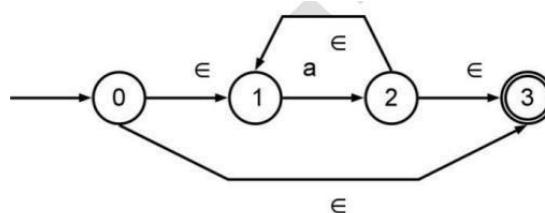
$$R1 = (a / b)$$

$$R2 = a$$

$$R3 = (a / b)$$

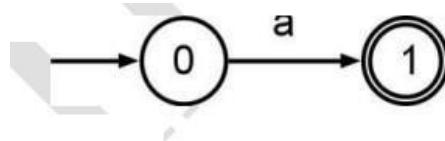
Thompson's Rules

**Rule for  $a^*$**

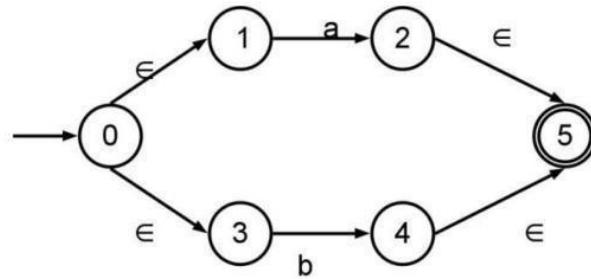




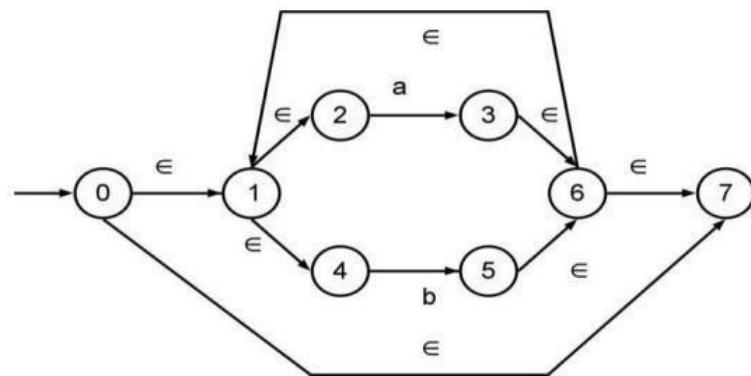
**Rule for a**



**Rule for a / b**

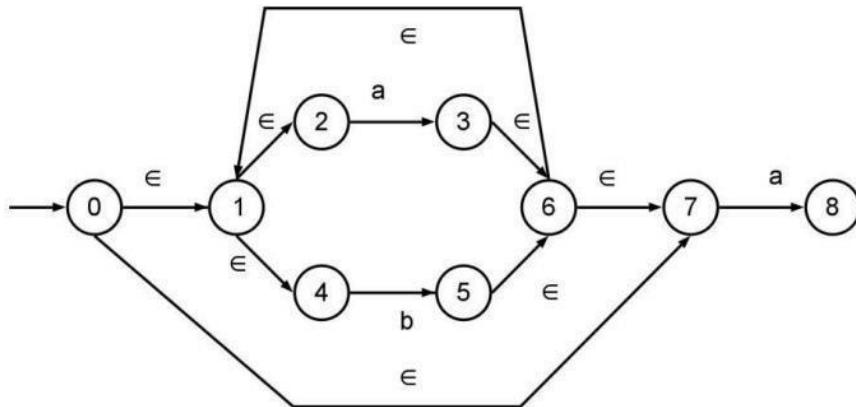


**R1: (a / b)\***

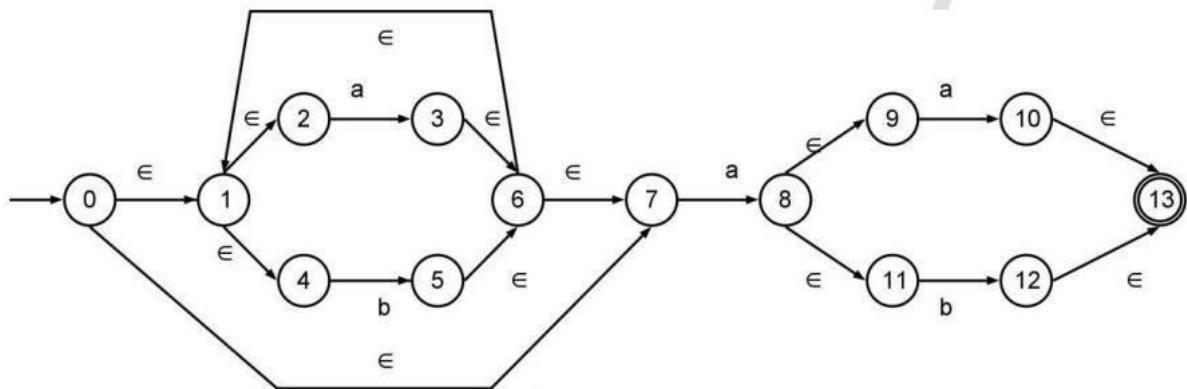




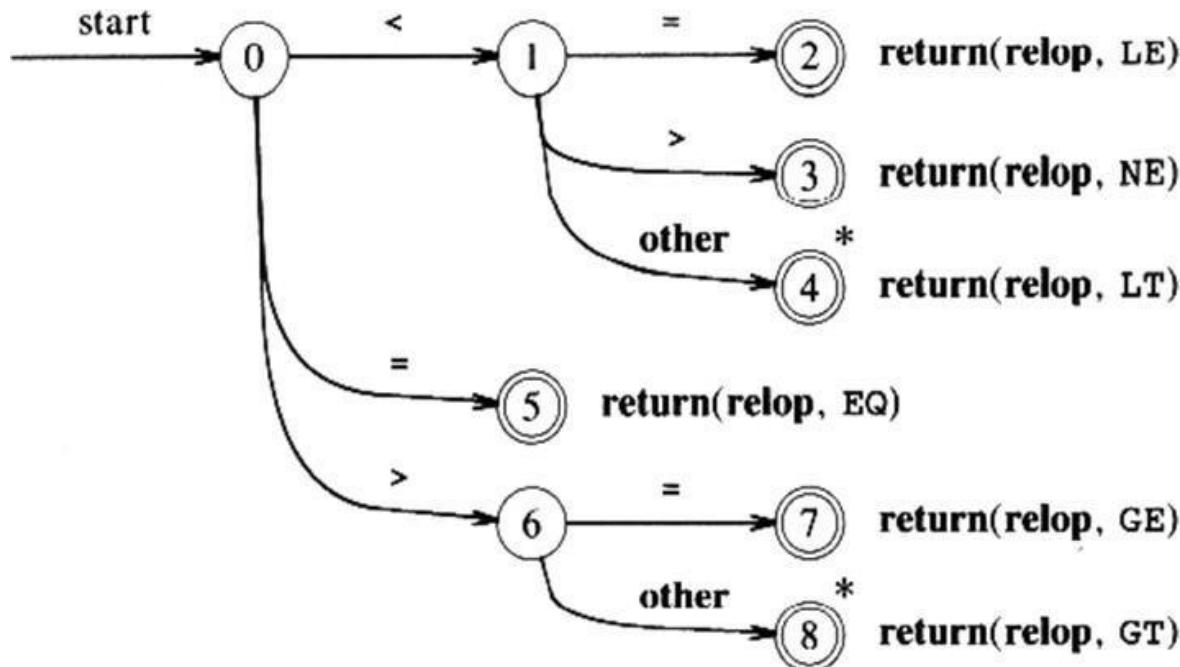
**R1 R2: (a / b)\* a**



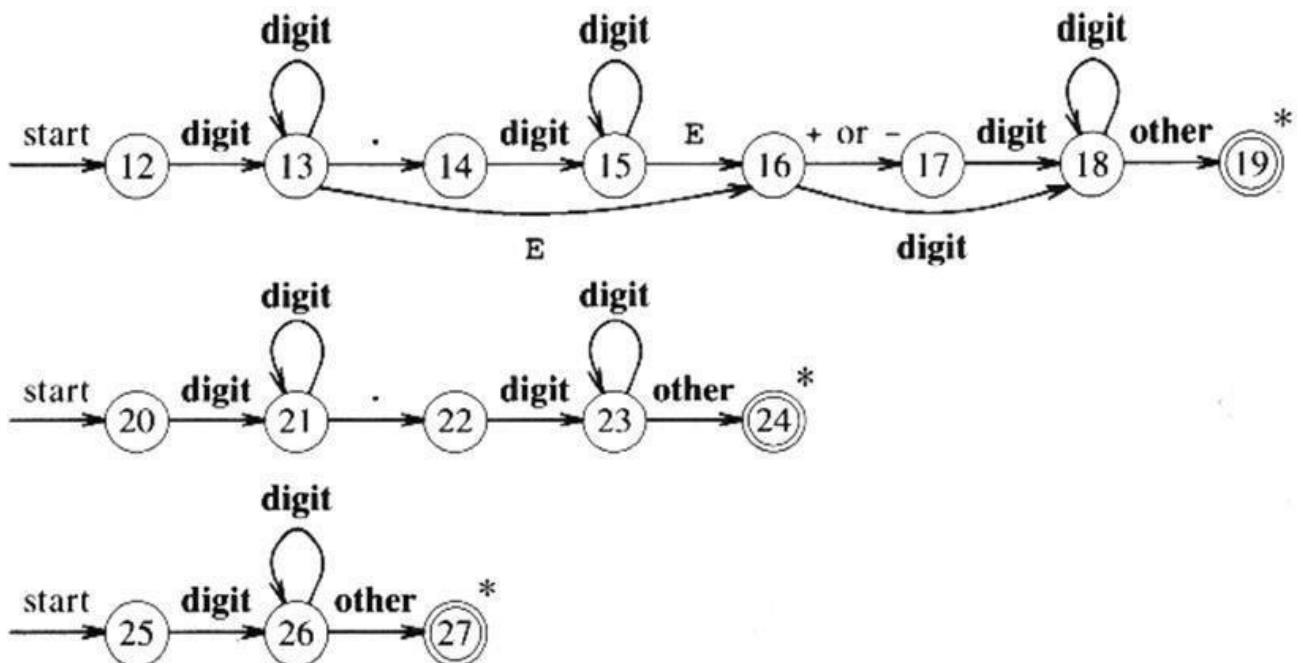
**R1 R2 R3: (a / b)\* a ( a / b )**



ii) Apply the principles of transition diagram construction to model relational operators and unsigned numbers in Pascal



Transition diagram for relational operator



Transition diagram for unsigned numbers in Pascal

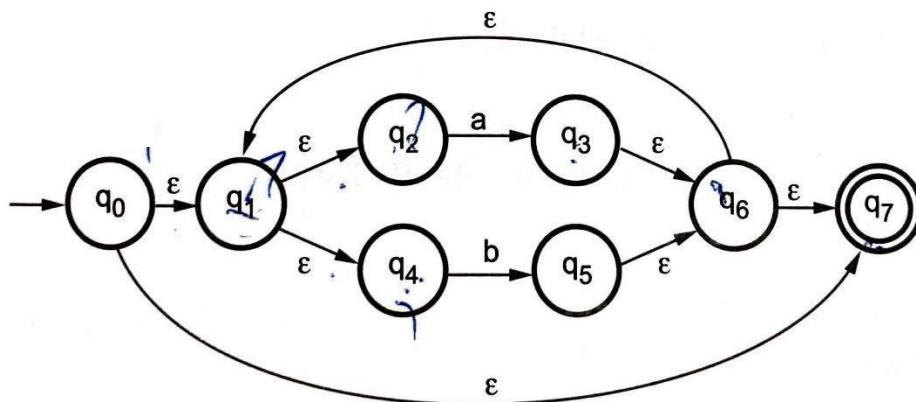
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**13. Apply DFA minimization techniques to demonstrate that the two given regular expressions are equivalent**

- a)  $(a \mid b)^*$
- b)  $(a^* \mid b^*)^*$

The NFA with  $\epsilon$  for  $(a \mid b)^*$  will be



We will eliminate  $\epsilon$  moves and convert it to DFA

$\epsilon$ -closure  $\{q_0\} = \{q_0, q_1, q_2, q_4, q_7\}$

$\epsilon$ -closure  $\{q_1\} = \{q_1, q_2, q_4\}$

$\epsilon$ -closure  $\{q_2\} = \{q_2\}$

$\epsilon$ -closure  $\{q_3\} = \{q_3, q_6, q_1, q_2, q_4, q_7\} = \{q_1, q_2, q_3, q_4, q_6, q_7\}$

$\epsilon$ -closure  $\{q_4\} = \{q_4\}$

$\epsilon$ -closure  $\{q_5\} = \{q_1, q_2, q_4, q_5, q_6, q_7\}$

$\epsilon$ -closure  $\{q_6\} = \{q_1, q_2, q_4, q_6, q_7\}$

$\epsilon$ -closure  $\{q_7\} = \{q_7\}$

consider  $\epsilon$ -closure  $\{q_0\} = \{q_0, q_1, q_2, q_4, q_7\} \rightarrow$  call it as state A

$$\delta'(A,a) = \epsilon\text{-closure } \{ \delta(A,a) \}$$

$$= \epsilon\text{-closure } \{ \delta(q_0, q_1, q_2, q_4, q_7), a \}$$

$$= \epsilon\text{-closure } \{ \delta(q_0, a) \cup \delta(q_1, a) \cup \delta(q_2, a) \cup \delta(q_4, a) \cup \delta(q_7, a) \}$$

$$= \epsilon\text{-closure } \{ q_3 \}$$

$$= \{q_1, q_2, q_3, q_4, q_6, q_7\} \rightarrow$$
 call it as state B

$$\delta'(A,a) = B$$

$$\delta'(A,a) = \epsilon\text{-closure } \{ \delta(q_0, q_1, q_2, q_4, q_7), b \}$$

$$= \epsilon\text{-closure } \{ q_5 \}$$

$$= \{q_1, q_2, q_4, q_5, q_6, q_7\} \rightarrow$$
 call it as state C

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$$\delta^*(A, b) = C$$

Now consider state B and C for input transitions.

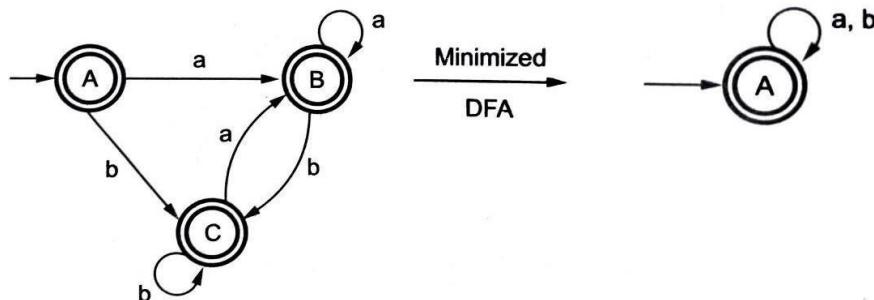
$$\begin{aligned}\delta^*(B, a) &= \epsilon\text{-closure } \{\delta(q_1, q_2, q_3, q_4, q_5, q_6, q_7), a\} \\ &= \epsilon\text{-closure } \{q_3\} \quad \text{i.e. state B.} \\ \delta^*(B, b) &= \epsilon\text{-closure } \{\delta(q_1, q_2, q_3, q_4, q_6, q_7), b\} \\ &= \epsilon\text{-closure } \{q_5\} \quad \text{i.e. state C.}\end{aligned}$$

**Similarly,**

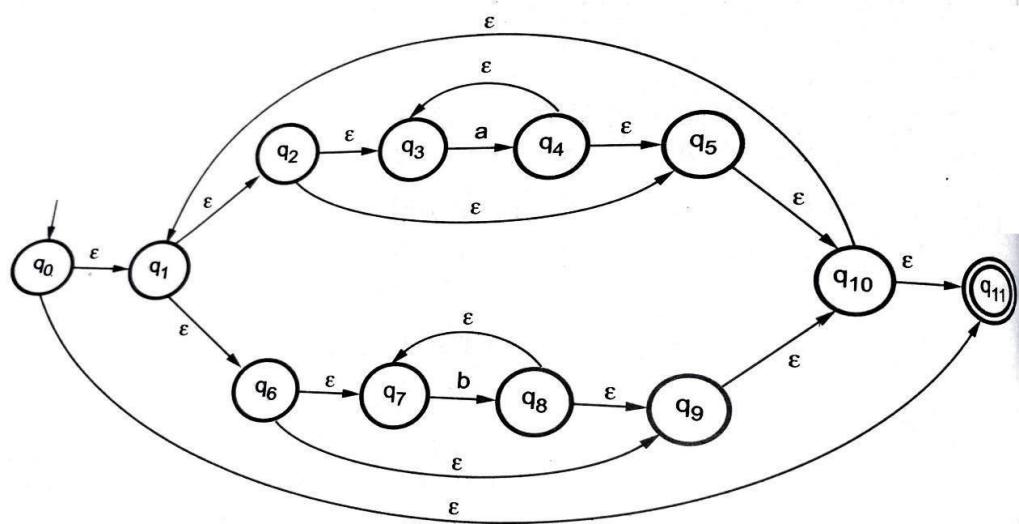
$$\begin{aligned}\delta^*(C, a) &= \epsilon\text{-closure } \{\delta(q_1, q_2, q_4, q_5, q_6, q_7), a\} \\ &= \text{state B}\end{aligned}$$

$$\delta^*(C, a) = \text{state C}$$

The DFA will be



The NFA with  $\epsilon$  for  $(a^* \mid b^*)^*$  will be



$$\epsilon\text{-closure } \{q_0\} = \{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8, q_9, q_{10}, q_{11}\} \rightarrow \text{call it as state A}$$

$$\delta^*(A, a) = \epsilon\text{-closure } \{\delta(A, a)\}$$

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$$\begin{aligned}
 &= \epsilon\text{-closure} \{ (q_0, q_1, q_2, q_3, q_5, q_6, q_7, q_9, q_{10}, q_{11}), a \} \\
 &= \epsilon\text{-closure} \{ q_4 \} \\
 &= \{ q_4, q_5, q_{10}, q_1, q_2, q_3, q_6, q_7, q_9, q_{11} \} \longrightarrow \text{call it as state B} \\
 \delta'(A, a) &= B \\
 \delta'(A, b) &= \epsilon\text{-closure} \{ \delta(A, b) \} \\
 &= \epsilon\text{-closure} \{ (q_0, q_1, q_2, q_3, q_5, q_6, q_7, q_9, q_{10}, q_{11}), b \} \\
 &= \epsilon\text{-closure} \{ q_8 \} \\
 &= \{ q_8, q_9, q_{10}, q_1, q_2, q_3, q_5, q_6, q_7, q_9, q_{11} \} \longrightarrow \text{call it as state C} \\
 \delta'(A, b) &= C \\
 \delta'(B, a) &= \epsilon\text{-closure} \{ \delta(B, a) \} \\
 &= \epsilon\text{-closure} \{ (q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_9, q_{10}, q_{11}), a \} \\
 &= \epsilon\text{-closure} \{ q_4 \} = B
 \end{aligned}$$

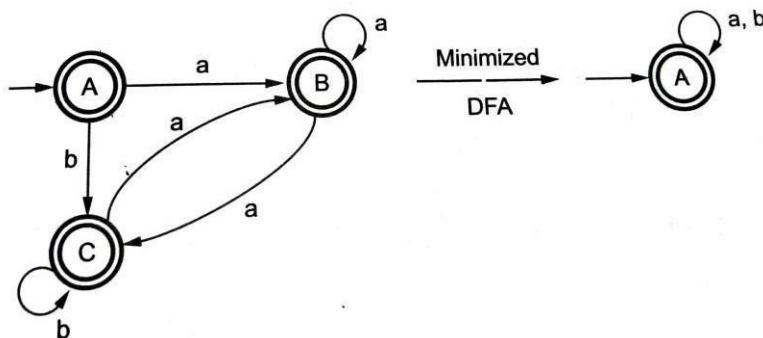
Similarly  $\delta'(B, b) = \epsilon\text{-closure} \{ q_8 \}$

$\delta'(B, b) = C$

$\delta'(C, a) = B$

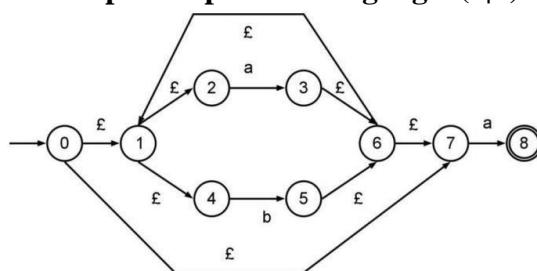
$\delta'(C, b) = C$

After eliminating  $\epsilon$  moves we get following DFA



Thus the DFA obtained in (i) and (ii) are the same. Hence  $(a \mid b)^* = (a^* \mid b^*)^*$  is proved.

#### 14. Design an appropriate DFA to accept the specified language $(a|b)^* a$



**Find the States of DFA**

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$\in$ - closure (0) =	$\{0,1,2,4,7\} = A$
Move (A, a) =	$\{3,8\}$
Move (A, b) =	$\{5\}$
$\in$ - Closure of ( Move (A, a) ) =	$\{3,6,7,1,2,4,8\}$
=	
=	$\{1,2,3,4,6,7,8\} = B$
$\in$ - closure of (Move (A, b) ) =	$\{5,6,7,1,2,4,\}$
=	$\{1,2,4,5,6,7\} = C$
Move (B, a) =	$\{3,8\}$
Move (B, b) =	$\{5\}$
$\in$ - closure ( Move(B, a) ) =	B
$\in$ - closure ( Move(B, b) ) =	C
Move (C, a) =	$\{3,8\}$
Move (C, b) =	$\{5\}$
$\in$ - closure ( Move(C, a) ) =	B
$\in$ - closure ( Move(C, b) ) =	C

### Construction of DTRAN of DFA

States	i/p Symbols	
	a	b
->A	B	C
*B	B	C
C	B	C

### Minimized DFA

$$\begin{aligned} &= (AC)(B) \\ &= A \end{aligned}$$

### MinDTRAN of DFA

States	i/p Symbols	
	a	b
->A	B	A
*B	B	A

### DFA

