Equivalence of NFA and DFA

(Construct a equivalent DFA from a given NFA)

Given: Transistion table

State \ Input	0	1
p	{p, q}	{p}
q	{r}	{r}
r	{s}	ϕ
s	{s}	{s}

Note:

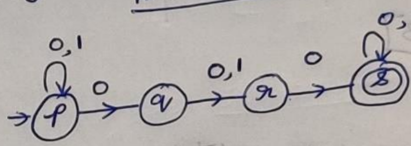
*) If the NFA FSM is not given, then the transistion table would be given.

*) If the ~~the~~ NFA FSM is given, then construct a transistion table from it.

Solution

*) Step-1 $M \Rightarrow \{Q, \Sigma, \delta, q_0, F\}$

NFA - transistion diagram



$Q \rightarrow \{p, q, r, s\}$

$\Sigma \Rightarrow \{0, 1\}$

δ $q_0 \Rightarrow \{p\} \Rightarrow p$

$F \Rightarrow s$

*) Step-II (Find the number of states in NFA)

$N \Rightarrow 4$ $\{p, q, r, s\}$

*) Step-III (Find the power set)

$Q_D \Rightarrow 2^N \Rightarrow 2^4 \Rightarrow 16$

*) Step-IV (Construct the sub-sets)

$Q_D \Rightarrow \{$ [ ], [p], [q], [r], [s],

[p, q], [p, r], [p, s],

[q, r], [q, s], [r, s],

[p, q, r], [p, q, s], [q, r, s], [p, r, s], [p, q, r, s]

Step-V (Transition table)

States	Input-symbol 0	1
[ ]	[ ]	[ ]
✓[p]	[p,q]	[p]
[q]	[r]	[r]
[r]	[s]	φ
[s]	[s]	[s]
✓[p,q]	[p,q,r]	[p,r]
✓[p,r]	[p,q,s]	[p]
✓[p,s]	[p,q,s]	[p,s]
[q,r]	[r,s]	[r]
[q,s]	[r,s]	[r,s]
[r,s]	[s]	[s]
✓[p,q,r]	[p,q,r,s]	[p,r]
✓[p,q,s]	[p,q,r,s]	[p,r,s]
✓[p,r,s]	[p,q,s]	[p,s]
[q,r,s]	[r,s]	[r,s]
✓[p,q,r,s]	[p,q,r,s]	[p,r,s]

*) Select the intial state & from that proceed further states.

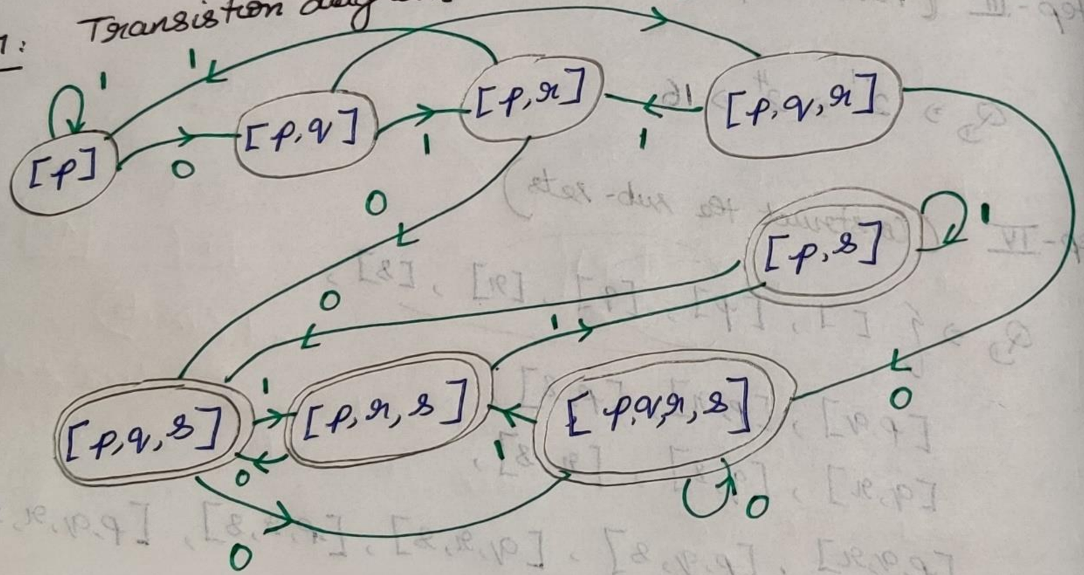
Step-6: Transistion states

$Q_D \Rightarrow \{ [p] ; [p,q] ; [p,r] ; [p,s] ; [p,q,r] ;$
$[p,q,s] ; [p,r,s] ; [p,q,r,s] \}$

States with s are final.

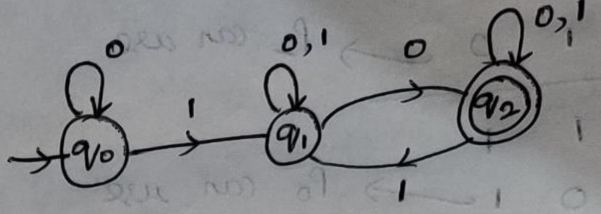
$F_D \Rightarrow \{ [p,s] ; [p,q,s] ; [p,r,s] ; [p,q,r,s] \}$

Step-7: Transistion diagram



Eg: 1

NFA



i) 010 ✓

ii) 11 ✗

State \ Input	0	1
A) q_0	$[q_0]$ A)	$[q_1]$ B)
B) q_1	$[q_1, q_2]$ D)	$[q_1]$ B)
C) * q_2	$[q_2]$ C)	$[q_1, q_2]$ D)

$(q_1, q_2)(0) \Rightarrow (q_1, q_2)$

$(q_1, q_2)(1) \Rightarrow (q_1, q_2)$

(q_1, q_2)

Table

	0	1
[A]	[A]	[B]
[B]	[D]	[B]
[D]	[D]	[D]

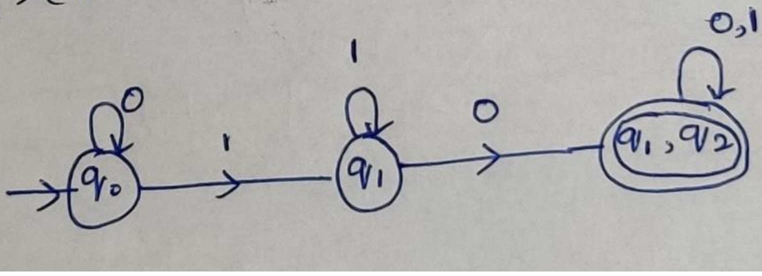
$[A] \Rightarrow (q_0)$

$[B] \rightarrow (q_1)$

$[D] \Rightarrow (q_1, q_2)$ *

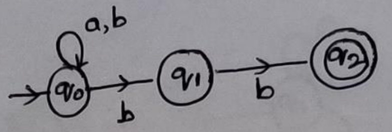
i) 010 ✓

ii) 11 ✗



⇒ Required DFA

NFA



Transition table

Input / States	a	b
A) q_0	A) $[q_0]$	$[q_0, q_1]$ E)
B) q_1	D) [illegible]	$[q_2]$ C)
C) q_2	D) [ ]	[ ] D)

Table

	a	b
[A]	[A]	[E]
[E]	[A]	[F]
[F]	[A]	[F]

$(q_0, q_1)\ (a) \Rightarrow (q_0)$

$(q_0, q_1)\ (b) \Rightarrow (q_0, q_1, q_2)$

New state $[F] \Rightarrow (q_0, q_1, q_2)$

$(q_0, q_1, q_2)\ (a) \Rightarrow (q_0)$

$(q_0, q_1, q_2)\ (b) \Rightarrow (q_0, q_1, q_2)$

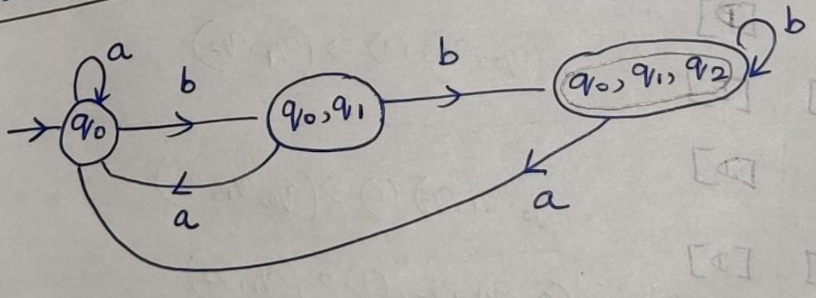
The states are

$[A] \Rightarrow q_0$ $\quad [D] \Rightarrow [\ ]$

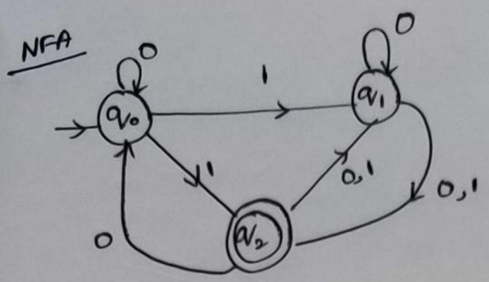
$[B] \Rightarrow q_1$ $\quad$ *) $[E] \Rightarrow (q_0, q_1)$

*) $[C] \Rightarrow q_2$ $\quad [F] \Rightarrow (q_0, q_1, q_2)$

Transistion diagram



NFA



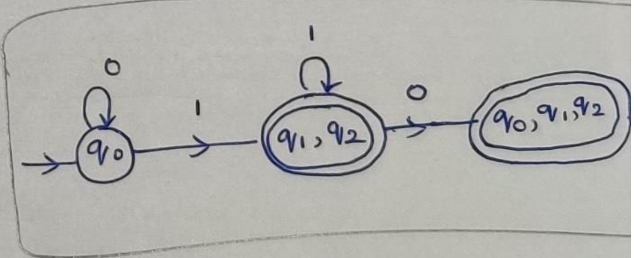
Input / States	0	1
A) q_0	A) [q_0]	[q_1, q_2] D)
B) q_1	D) [q_1, q_2]	[q_2] C)
C) q_2	[q_0, q_1] E)	[q_1] B)

(F) ⇒ (q_0, q_1, q_2)

(q_0, q_1, q_2)(0) ⇒ (q_0, q_1, q_2)

(q_0, q_1, q_2)(1) ⇒ (q_1, q_2)

Input / States	0	1
[A]	[A]	[D]
[D]	~~[q_0, q~~[F]	[D]
[F]	[F]	[D]

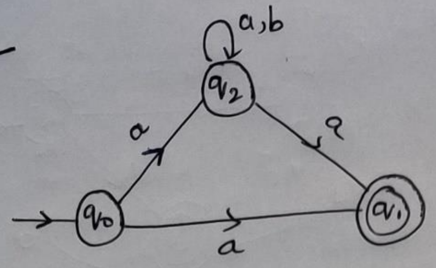


[A] ⇒ {q_0} D ⇒ {q_1, q_2}

[B] ⇒ {q_1} E ⇒ {q_0, q_1}

[C] ⇒ {q_2} F ⇒ {q_0, q_1, q_2}

NFA



Input / states	a	b
A) q_0	D) $[q_1, q_2]$	[ ] E)
B) q_1	D) [ ]	[ ] E)
C) q_2	D) $[q_1, q_2]$	$[q_2]$ C)

Input / states	a	b
[A]	[D]	[E]
*) [D]	[D]	[C]
[C]	[D]	[C]

$(q_0, a) \to q_2, q_1$

$(q_1, q_2)(a) \Rightarrow (q_1, q_2)$

$(q_1, q_2)(b) \Rightarrow (q_2)$

$[A] \Rightarrow \{q_0\}$

$[B] \Rightarrow \{q_1\}$

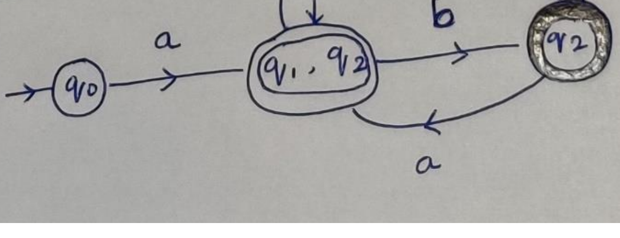
$[C] \Rightarrow \{q_2\}$

$[D] \Rightarrow \{q_1, q_2\}$

$[E] \Rightarrow \{\ \}$

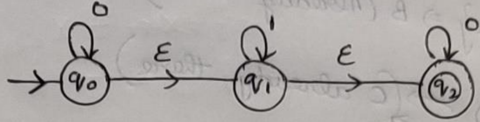
DFA

Transistion-diagram



2) Convert epsilon NFA to DFA

Question



Solution

ε closure of $(q_0) \Rightarrow \{q_0, q_1, q_2\} \Rightarrow A$ New state found

ε closure of $(q_1) \Rightarrow \{q_1, q_2\}$

ε closure of $(q_2) \Rightarrow \{q_2\}$

Transition for the new state

$\delta(A,0) \Rightarrow \{\delta(q_0,0) \cup \delta(q_1,0) \cup \delta(q_2,0)\}$

$\Rightarrow \{(q_0) \cup (\phi) \cup (q_2)\}$

$\Rightarrow \{q_0, q_2\}$ New

$\delta(A,1) \Rightarrow \{\delta(q_0,1) \cup \delta(q_1,1) \cup \delta(q_2,1)\}$

$\Rightarrow \{(\phi) \cup (q_1) \cup (q_2)\}$

$\Rightarrow \{q_1, q_2\}$ New

ε-closure of $(q_0, q_2) \Rightarrow \{q_0, q_1, q_2\} \to$ A (already there)

ε-closure of $(q_1, q_2) \Rightarrow \{q_1, q_2\} \Rightarrow B$ (New state found)

$\delta(B,0) \Rightarrow \{\delta(q_1,0) \cup \delta(q_2,0)\} \Rightarrow \{q_2\}$ (new)

$\delta(B,1) \Rightarrow \{\delta(q_1,1) \cup \delta(q_2,1)\} \Rightarrow \{q_1, q_2\} \to$ B (already there)

$\boxed{\varepsilon \text{ closure of } q_2 \Rightarrow \{q_2\} \Rightarrow C \text{ (New state)}}$

ε closure of $(q_1, q_2) \Rightarrow \{q_1, q_2\} \Rightarrow B$ (Already there)

$\delta(C,0) \Rightarrow \delta(q_2,0) \Rightarrow (q_2)$ → (C already there)

$\delta(C,1) \Rightarrow \delta(q_2,1) \Rightarrow (q_2)$

Transistion table

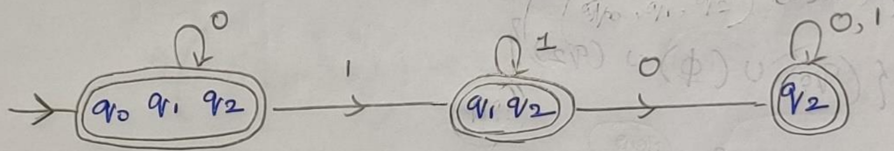
		0	1
→*	A	A	B
*	B	C	B
*	C	C	C

See all the epsilon closure answers

$A \Rightarrow \{q_0, q_1, q_2\}$

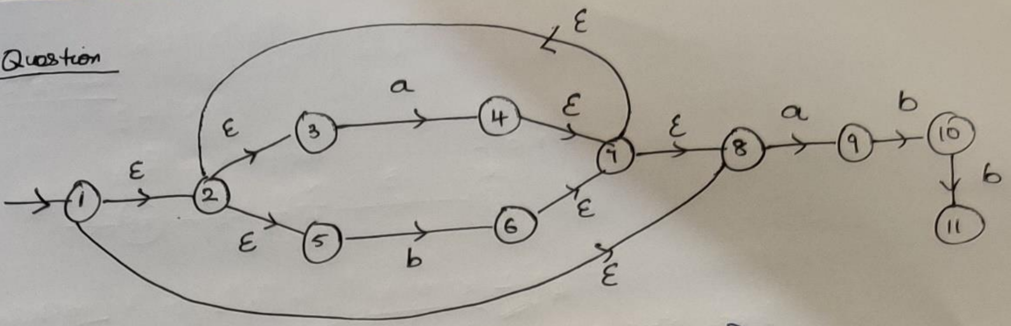
$B \Rightarrow \{q_1, q_2\}$

$C \Rightarrow \{q_2\}$



This is the required DFA

Question



ε closure of 1 ⇒ $\{1,2,8,3,5\}$ ⇒ A (New state)

~~ε closure~~

$\delta(A,a) \Rightarrow \{4,9\}$

$\delta(A,b) \Rightarrow \{6\}$

ε closure of (4,9) → $\{4,9,7,8,2,3,5\}$ ⇒ B (New state)

ε closure of (6) ⇒ $\{6,7,2,3,5,8\}$ ⇒ C (New state)

$\delta(B,a) \Rightarrow \{4,9\}$ → B (already)

$\delta(B,b) \Rightarrow \{6,10\}$

$\delta(C,a) \Rightarrow \{4,9\}$ → B (already)

$\delta(C,b) \Rightarrow \{6\}$ → C (already)

ε closure of (6,10) ⇒ $\{6,7,8,2,3,5,10\}$ ⇒ D (New state)

$\delta(D,a) \Rightarrow \{4,9\}$ → B (already)

$\delta(D,b) \Rightarrow \{6,11\}$

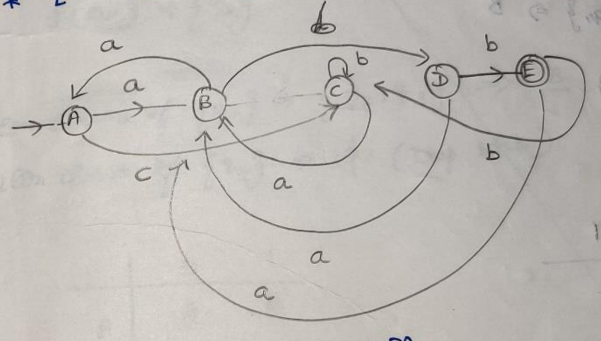
ε closure of (6,11) → $\{6,7,2,3,5,11\}$ → E (New state)

$\delta(E,a) \Rightarrow \{6\}$ → C (already)

$\delta(E,b) \Rightarrow \{6\}$

Transistion table

	a	b
→ A	B	C
B	B	D
C	B	C
D	B	E
* E	B	C

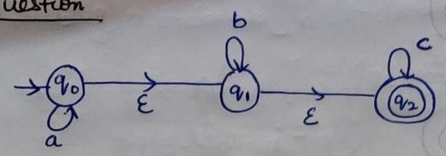


This is the required DFA

3)Convert epsilon NFA to epsilon NFA

$$\delta'(q_i, x) \Rightarrow \epsilon\text{-closure}\left[\delta\left(\epsilon\text{-closure}(q_i), x\right)\right]$$

Question



Solution:

States	ϵ-closure
q_0	$q_0\ q_1\ q_2$
q_1	$q_1\ q_2$
q_2	q_2

$$\delta'(q_i, x) \Rightarrow \epsilon\text{-closure}\left[\delta\left(\epsilon\text{-closure}(q_i), x\right)\right]$$

*) $\delta(q_0, a) \Rightarrow \epsilon\text{-closure}\left[\delta\left(\epsilon\text{-closure}(q_0), a\right)\right]$

$\Rightarrow \epsilon\text{-closure}\left[\delta\left(q_0, q_1, q_2\right), a\right]$

$\Rightarrow \epsilon\text{-closure}\left([q_0]\right)$

$\boxed{\delta(q_0, a) \Rightarrow (q_0, q_1, q_2)}$

*) $\delta(q_0, b) \Rightarrow \epsilon\text{-closure}\left[\delta\left(\epsilon\text{-closure}(q_0), b\right)\right]$

$\Rightarrow \epsilon\text{-closure}\left[\delta\left(q_0, q_1, q_2\right), b\right]$

$\Rightarrow \epsilon\text{-closure}\left(q_1\right)$

$\boxed{\delta(q_0, b) \Rightarrow q_1, q_2}$

*) $\delta(q_0, c) \Rightarrow \varepsilon\text{-closure}\left[\delta(\varepsilon\text{-closure}(q_0), c)\right]$

$\Rightarrow \varepsilon\text{-closure}\left[\delta(q_1, q_2, q_0), c\right]$

$\Rightarrow \varepsilon\text{-closure}\left[q_2\right]$

$\boxed{\delta(q_0, c) \Rightarrow q_2}$

———— × ———— × ————

*) $\delta(q_1, a) \Rightarrow \varepsilon\text{-closure}\left[\delta(\varepsilon\text{-closure}(q_1), a)\right]$

$\Rightarrow \varepsilon\text{-closure}\left[\delta(q_1, q_2), a\right]$

$\Rightarrow \varepsilon\text{-closure}(\phi)$

$\boxed{\delta(q_1, a) \Rightarrow \phi}$

*) $\delta(q_1, b) \Rightarrow \varepsilon\text{-closure}\left[\delta(\varepsilon\text{-closure}(q_1), b)\right]$

$\Rightarrow \varepsilon\text{-closure}\left[\delta(q_1, q_2, b)\right]$

$\Rightarrow \varepsilon\text{-closure}(q_1)$

$\boxed{\delta(q_1, b) \Rightarrow q_1, q_2}$

*) $\delta(q_1, c) \Rightarrow \varepsilon\text{-closure}\left[\delta(\varepsilon\text{-closure}(q_1), c)\right]$

$\Rightarrow \varepsilon\text{-closure}\left[\delta(q_1, q_2), c\right]$

$\Rightarrow \varepsilon\text{-closure}(q_2)$

$\boxed{\delta(q_1, c) \Rightarrow q_2}$

———— × ———— × ————

*) $\delta(q_2, a) \Rightarrow \varepsilon\text{-closure}[\delta(\varepsilon\text{-closure}(q_2); a)]$

$\Rightarrow \varepsilon\text{-closure}[\delta(q_2, a)]$

$\Rightarrow \varepsilon\text{-closure}(\phi)$

$\boxed{\delta(q_2, a) \Rightarrow \phi}$

*) $\delta(q_2, b) \Rightarrow \varepsilon\text{-closure}[\delta(\varepsilon\text{-closure}(q_2), b)]$

$\Rightarrow \varepsilon\text{-closure}(\delta(q_2, b))$

$\Rightarrow \varepsilon\text{-closure}(\phi)$

$\boxed{\delta(q_2, b) \Rightarrow \phi}$

*) $\delta(q_2, c) \Rightarrow \varepsilon\text{-closure}[\delta(\varepsilon\text{-closure}(q_2), c)]$

$\Rightarrow \varepsilon\text{-closure}(\delta(q_2, c))$

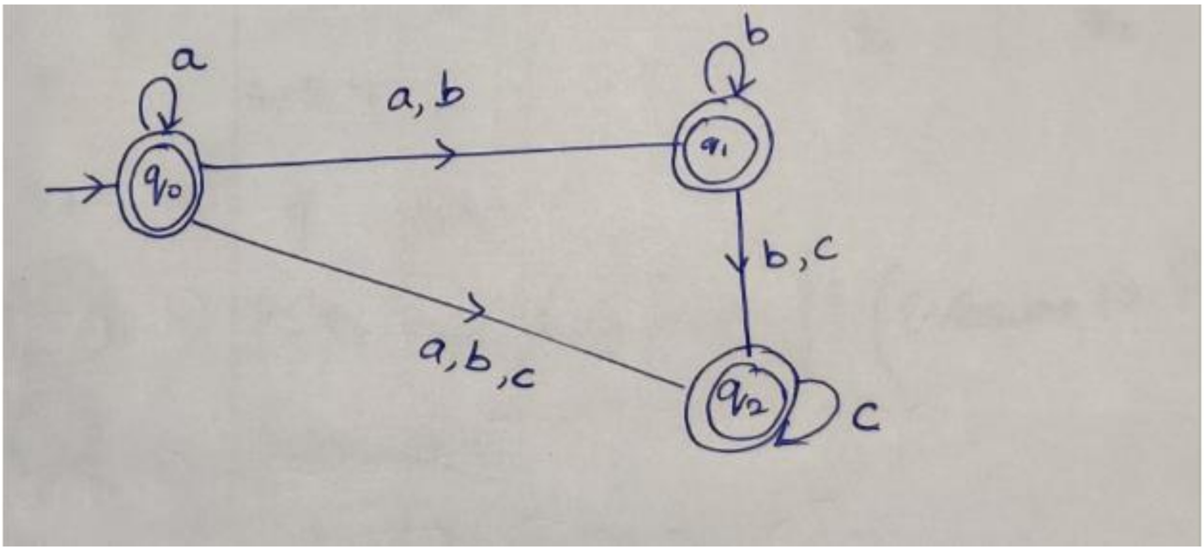
$\Rightarrow \varepsilon\text{-closure}(q_2)$

$\boxed{\delta(q_2, c) \Rightarrow q_2}$

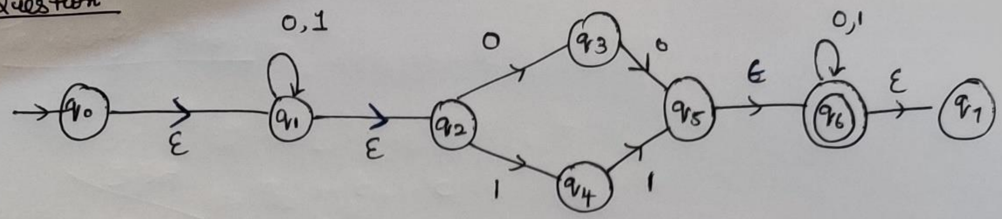
———— x ———— x ————

Transistion table

State \ Input	a	b	c
→ q_0	$q_0\, q_1, q_2$	q_1, q_2	q_2
q_1	ϕ	q_1, q_2	q_2
q_2	ϕ	ϕ	q_2



Question

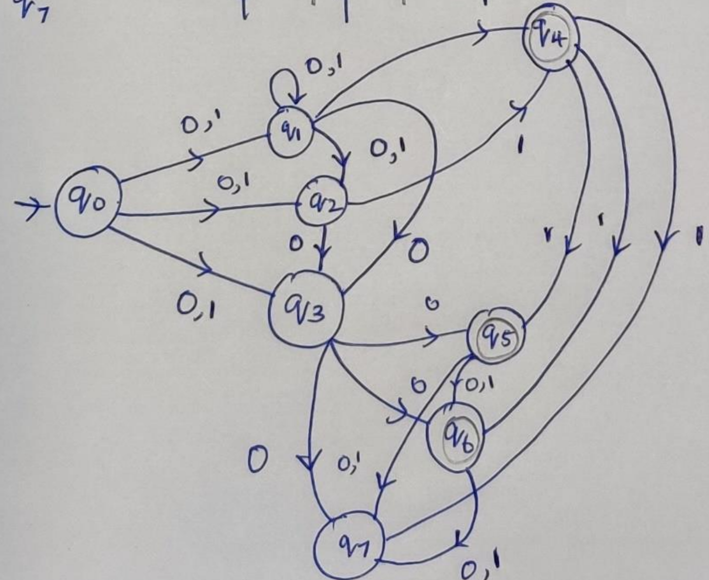


Solution

states	ε-closure
q_0	$q_0\ q_1\ q_2$
q_1	$q_1\ q_2$
q_2	q_2
q_3	q_3
q_4	q_4
* q_5	$q_5\ q_6\ q_7$
* q_6	$q_6\ q_7$
q_7	q_7

Input / states	0	1
$\rightarrow q_0$	$q_1\ q_2\ q_3$	$q_1\ q_2\ q_4$
q_1	$q_1\ q_2\ q_3$	$q_1\ q_2\ q_4$
q_2	q_3	q_4
q_3	$q_5\ q_6\ q_7$	ϕ
q_4	ϕ	$q_5\ q_6\ q_7$
q_5	$q_6\ q_7$	$q_6\ q_7$
q_6	$q_6\ q_7$	$q_6\ q_7$
q_7	ϕ	ϕ

$\delta'(q_i, x)$ ε-closure $\left[\delta\left(\varepsilon\text{-closure}(q_i)\right), x)\right]$



Minimization of DFA (Myhill-Nerode Theorem)

Equivalence of a state

For all possible input if one state goes to a final state then other state should also go to the final state.

Distinguishable states

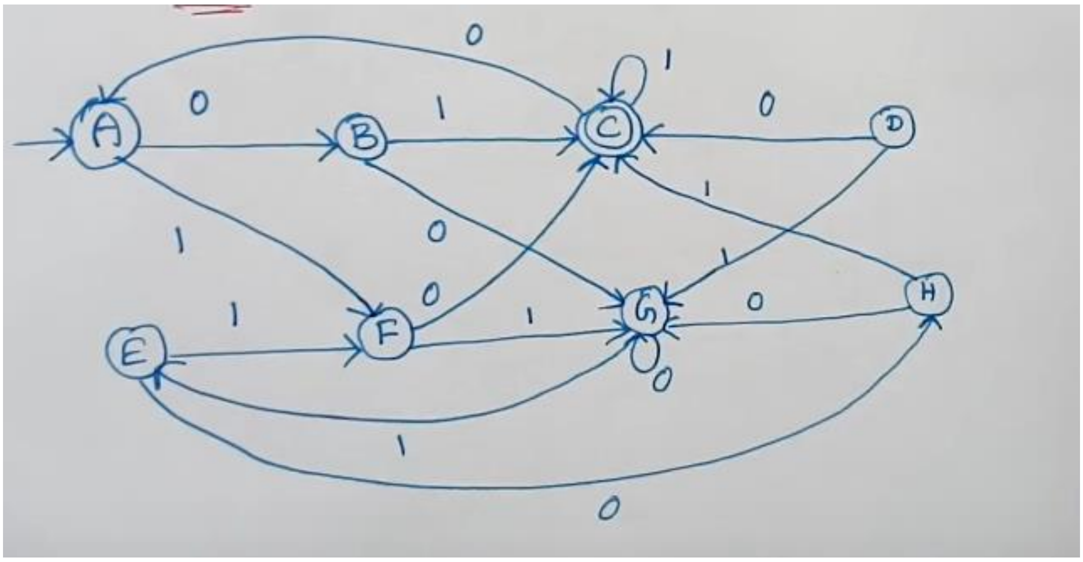
On any one possible input if one state goes to the final state and other doesn't go to the final, then the two states are said to be distinguishable states.

Eg: F → C(Final state)

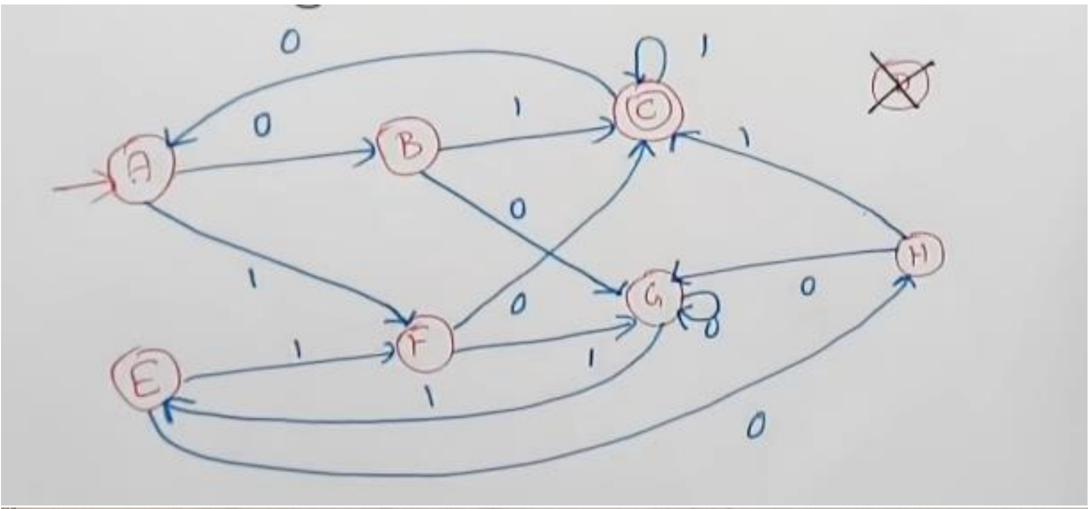
E → F

Then E and F are said to be distinguishable states.

Question



D is a not reachable state, So after removing D



Solution:

One state is not combined with itself.

(i.e) A is not combined with A

	A	B	C	E	F	G
B	X					
C	X	X				
E	? O	X	X			
F	X	X	X	X		
G	? X	X	X	? X	X	
H	X	? O	X	X	X	X

*) If the input is ϵ, final state remains itself and all the non-final state remains itself.

So C is distinguishable to all other states.

	0	1
A	B	F
B	G	C
C	A	C
E	H	F
F	C	G
G	G	E
H	G	C

*) When input is 0

F goes to final state $\boxed{C}$

F goes to non-final state {A, B, C, E, G, H}.

F is distinguisable.

*) When input is 1 :

B, C and H goes to the final state $\boxed{C}$

A, F, G, E goes to non-final state

B is distinguishable to ~~{B,C,H}~~ {A, F, G, E}

C is distinguishable to {A, F, G, E}

H is distinguishable to {A, F, G, E}

*) Check B and H ; same state for both the inputs

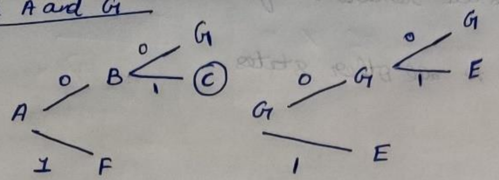
So B and H are equivalent states.

*) Check E and A ; for input 0 ; B and H (both are equivalent

for input 1 ; goes to F.

So E and A are equivalent states.

*) Check A and G

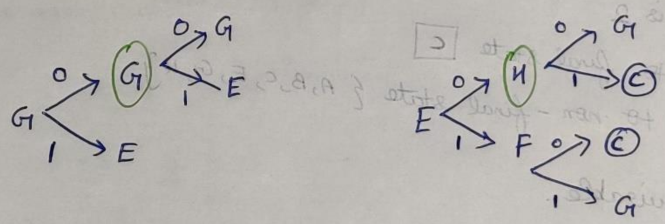


With 0 1 ⇒ C
A can reach
the final state

With 0 1 ⇒ E
G cannot reach
the final state

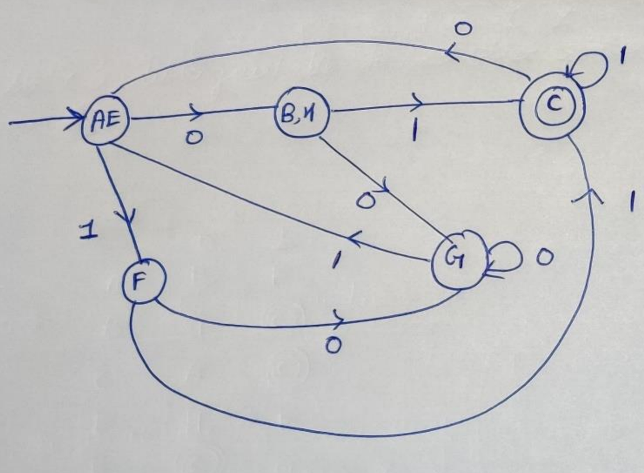
So A and G are distinguishable states.

*) check for G and E



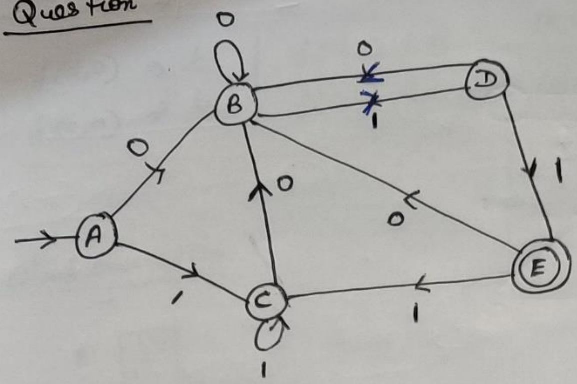
So G and E are distinguishable states.

Transistion diagram



Question

Question



Solution

	A	B	C	D
B	✓			
C		✓		
D	✓	✓	✓	
E	✓	✓	✓	✓

*) Check (b,a)

$\delta(b,0) \Rightarrow b$ | $\delta(b,1) \Rightarrow d$

$\delta(a,0) \Rightarrow b$ | $\delta(a,1) \Rightarrow c$

d,c is Not marked leave it

*) Check (c,a)

$\delta(c,0) \rightarrow b$ | $\delta(c,1) \rightarrow c$

$\delta(a,0) \Rightarrow b$ | $\delta(a,1) \rightarrow c$

*) Check (c,b)

$\delta(c,0) \Rightarrow b$ | $\delta(c,1) \Rightarrow c$

$\delta(b,0) \Rightarrow b$ | $\delta(b,1) \rightarrow d$

$\delta(d,a)$

$\delta(d,0) \Rightarrow b$ | $\delta(d,1) \Rightarrow e$
$\delta(a,0) \Rightarrow b$ | $\delta(a,1) \Rightarrow c$

(e,c) is Marked; so (d,a) should be marked.

Check (d,b)

$\delta(d,0) \Rightarrow b$ | $\delta(d,1) \Rightarrow e$
$\delta(b,0) \Rightarrow b$ | $\delta(b,1) \Rightarrow d$

(e,d) is marked so (d,b) should be marked.

Check (d,c)

$\delta(d,0) \Rightarrow b$ | $\delta(d,1) \Rightarrow e$
$\delta(c,0) \Rightarrow b$ | $\delta(c,1) \Rightarrow c$

(e,c) is marked, so (d,c) should be marked.

Check once again

B	✓	
C		✓
	A	B

Check for (b,a)

* $\delta(b,0) \Rightarrow b$ | $\delta(b,1) \Rightarrow d$
* $\delta(a,0) \Rightarrow b$ | $\delta(a,1) \Rightarrow c$

(d,c) is marked, so (b,a) should be marked

check for (c,a)

$\delta(c,0) \Rightarrow b$ | $\delta(c,1) \Rightarrow c$
$\delta(a,0) \Rightarrow b$ | $\delta(a,1) \Rightarrow c$

Check for (c,b)

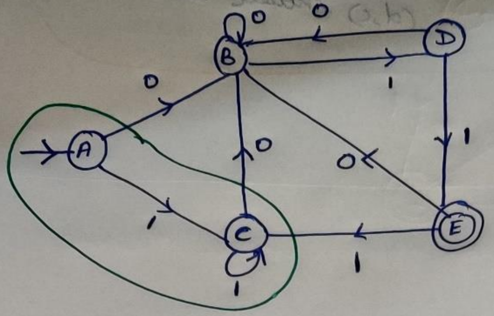
$\delta(c,0) \Rightarrow b$ | $\delta(c,1) \Rightarrow c$
$\delta(b,0) \Rightarrow b$ | $\delta(b,1) \Rightarrow d$

(c,d) | (d,c) is marked. So (c,b) should be marked

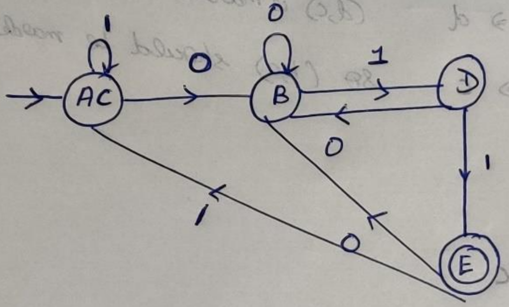
Combining all-un-marked pairs

1) (c,a) } c,a are combined together as a single state.

Transistion diagram

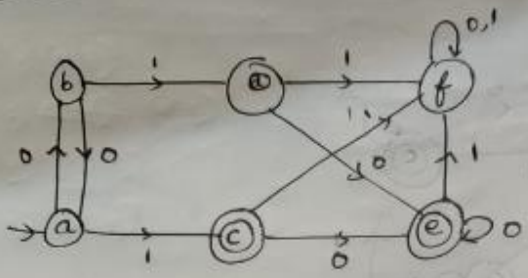


Final



Question

Question



Solution

There are no non-readable states

b					
c	✓	✓			
d	✓	✓			
e	✓	✓			
f	✓	✓	✓	✓	✓
	a	b	c	d	e

Mark if
final - non-final

Don't Mark if
non final - non final

*) If the input is ε, final

*) Un-marked pairs

1) (b,a)

For input ⇒ 0 :

$\delta(b,0) \Rightarrow a$
$\delta(a,0) \Rightarrow b$ } Check whether ab is marked, If No leave

For input ⇒ 1

$\delta(b,1) \Rightarrow d$
$\delta(a,1) \Rightarrow c$ }

2) (d,c)

0 $\delta(d,0) \Rightarrow e$
$\delta(c,0) \Rightarrow e$

1 $\delta(d,1) \Rightarrow f$
$\delta(c,1) \Rightarrow f$

3) (e,c)

0 $\delta(e,0) \Rightarrow e$
$\delta(c,0) \Rightarrow e$

1 $\delta(e,1) \Rightarrow f$
$\delta(c,1) \Rightarrow f$

4) (e,d)

0 $\delta(e,0) \Rightarrow e$
$\delta(d,0) \Rightarrow e$

1 $\delta(e,1) \Rightarrow f$
$\delta(d,1) \Rightarrow f$

5) (f,a)

0 $\delta(f,0) \Rightarrow f$
$\delta(a,0) \Rightarrow b$ } Check fb marked, If No leave

1 $\delta(f,1) \Rightarrow f$
$\delta(a,1) \Rightarrow c$ } fc is marked, Now mark fa also

6) (f,b)

0 $\delta(f,0) \Rightarrow f$
$\delta(b,0) \Rightarrow a$ } fa is marked Now mark fb also

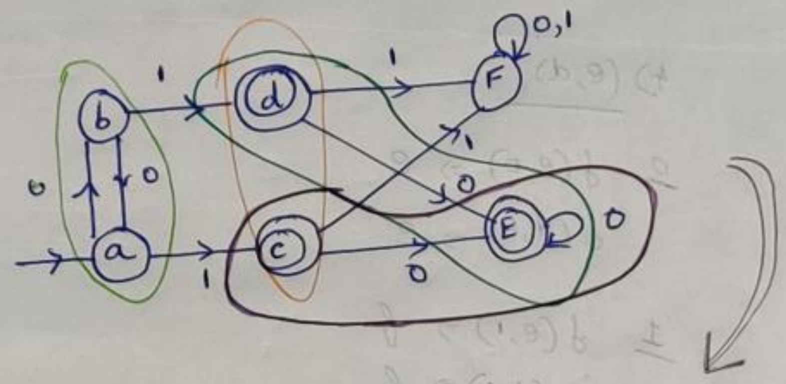
1 $\delta(f,1) \Rightarrow f$
$\delta(b,1) \Rightarrow a$

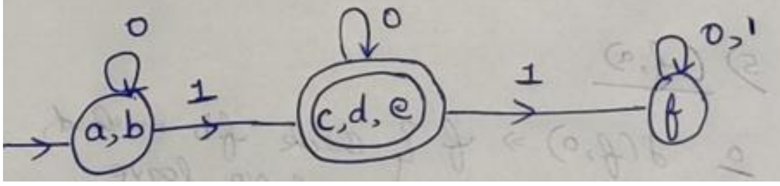
*) Combining all un-marked pairs

1) (a,b)
2) ~~(c,d)~~ (d,c)
3) (e,c)
4) (e,d)

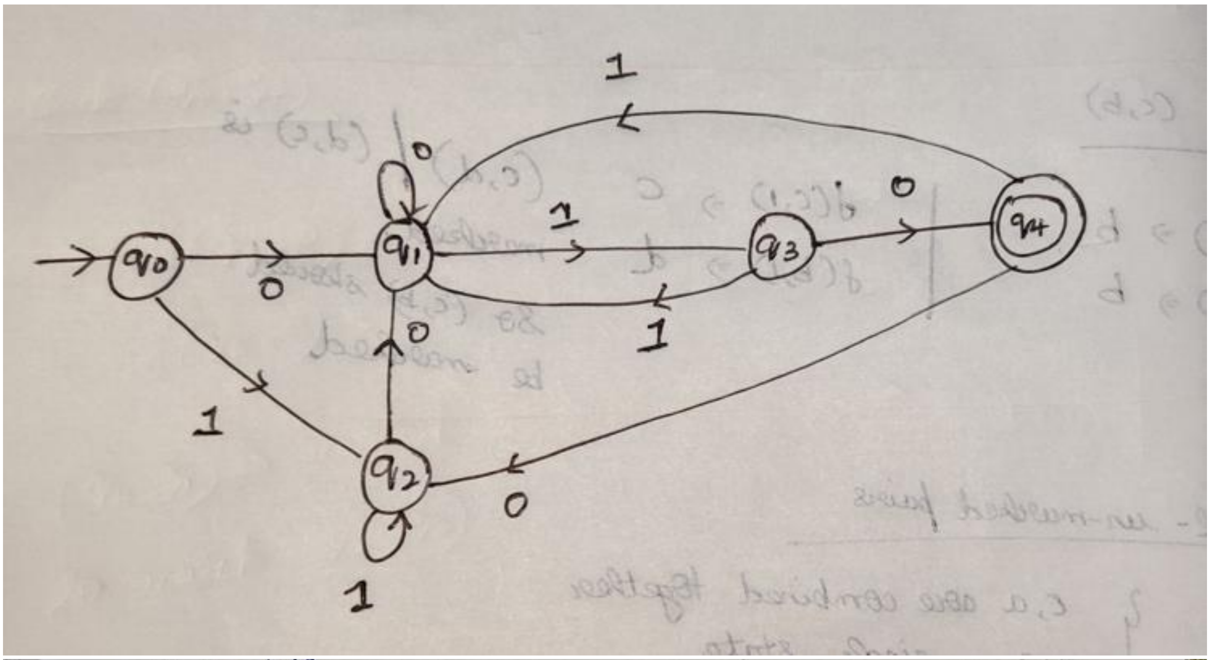
Combine them and make as a single state.

Transision diagram





Question



Transition table

	0	1
→ q_0	q_1	q_2
q_1	q_1	q_3
q_2	q_1	q_2
q_3	q_4	q_1
*) q_4	q_2	q_1

q_1				
q_2				
q_3	✓	✓	✓	
q_4	✓	✓	✓	✓
	q_0	q_1	q_2	q_3

Check (q_1, q_0)

$\delta(q_1, 0) \Rightarrow q_1$ | $\delta(q_1, 1) \Rightarrow q_3$

$\delta(q_0, 0) \Rightarrow q_1$ | $\delta(q_0, 1) \Rightarrow q_2$

Check (q_2, q_0)

$\delta(q_2, 0) \Rightarrow q_1$ | $\delta(q_2, 1) \Rightarrow q_2$

$\delta(q_0, 0) \Rightarrow q_1$ | $\delta(q_0, 1) \Rightarrow q_2$

Check (q_2, q_1)

$\delta(q_2, 0) \Rightarrow q_1$

$\delta(q_1, 0) \Rightarrow q_1$

$\delta(q_2, 1) \Rightarrow q_2$

$\delta(q_1, 1) \Rightarrow q_3$

Check (q_3, q_0)

$\delta(q_3, 0) \Rightarrow q_4$

$\delta(q_0, 0) \Rightarrow q_1$

$\left.\begin{array}{l} \delta(q_3, 0) \Rightarrow q_4 \\ \delta(q_0, 0) \Rightarrow q_1 \end{array}\right\}$ (q_4, q_1) is marked so mark (q_3, q_0)

Check (q_3, q_1)

$\delta(q_3, 0) \Rightarrow q_4$

$\delta(q_1, 0) \Rightarrow q_1$

$\delta(q_3, 1) \Rightarrow q_1$

$\delta(q_1, 1) \Rightarrow q_3$

(q_4, q_1) is marked, so (q_3, q_1) should be marked

Check (q_3, q_2)

$\delta(q_3, 0) \Rightarrow q_4$

$\delta(q_2, 0) \Rightarrow q_1$

$\delta(q_3, 1) \Rightarrow q_1$

$\delta(q_2, 1) \Rightarrow q_2$

(q_4, q_1) is marked

so mark (q_3, q_2)

Once again

q_1	✓	
q_2		✓
	q_0	q_1

check (q_1, q_0)

$\delta(q_1, 0) \Rightarrow q_1$

$\delta(q_0, 0) \Rightarrow q_1$

$\left.\begin{array}{l}\delta(q_1, 1) \Rightarrow q_3 \\ \delta(q_0, 1) \Rightarrow q_2\end{array}\right\}$ (q_3, q_2) is marked so (q_1, q_0) should be marked.

Check (q_2, q_0)

$\delta(q_2, 0) \Rightarrow q_1$ | $\delta(q_2, 1) \Rightarrow q_2$

$\delta(q_0, 0) \Rightarrow q_1$ | $\delta(q_0, 1) \Rightarrow q_2$

Check (q_2, q_1)

$\delta(q_2, 0) \Rightarrow q_1$ | $\delta(q_2, 1) \Rightarrow q_2$

$\delta(q_1, 0) \Rightarrow q_1$ | $\delta(q_1, 1) \Rightarrow q_3$

(q_2, q_3) | (q_3, q_2) is marked, so (q_2, q_1) should be marked

Un-marked states

(q_2, q_0)

Transistion diagram