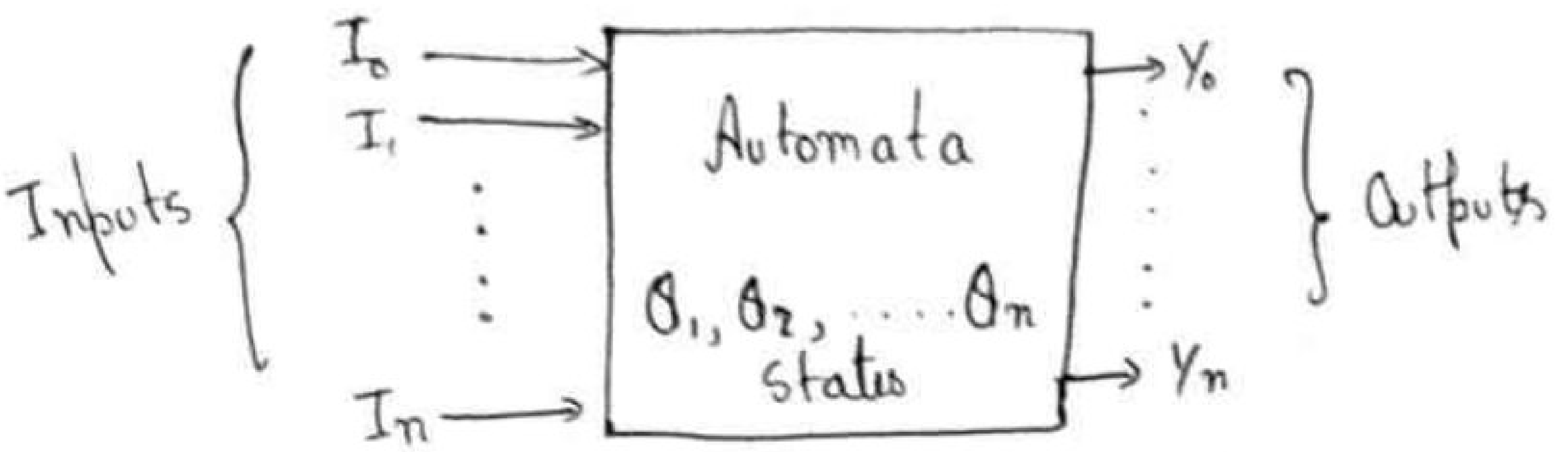
Automata Theory



A system should do / perform tasks without involvement of Human. This is called Automata

(i) Automata with Memory :- Output depends only on inputs

(ii) Moore Model :- Output depends only on States

(iii) Mealey Model :- Output depends ~~only~~ on States & Inputs

(i) Symbols :- Basic building blocks (Letters + digits + characters)

Symd

(ii) Alphabets (Σ) :- $\Sigma = \{0,1\}$ $\Sigma = \{a,b\}$ $\Sigma = \{A, \ldots, Z\}$

Always finite values

(iii) Strings (w) :- Sequence of characters (or) symbols

$|w| \rightarrow$ Finite String $\quad \varepsilon \rightarrow$ String does not have any value (NULL)

(iv) Languages :-

- Represented using different alphabets
- It may be finite (or) infinite. $L_1 = \{a,b\} = \{aa, ab, ba, bb\}$

Finite

$$L = \{a\}$$

$$\underset{\text{Infinite Language}}{\downarrow} = \{a, aa, aaa, \ldots\ldots\}$$

=> Finite Automata (DFA)

Deterministic Finite Automata

It can be represented by 5 Tuples

$$M = \{q, \Sigma, \delta, q_0, F\}$$

$q \to$ Finite Set of States

$\Sigma \to$ ~~Symbols~~ Finite Set of Alphabets.

$\delta \to$ Transition function $(\delta : q_0 \times \Sigma \to q_r)$

$q_0 \to$ Initial State

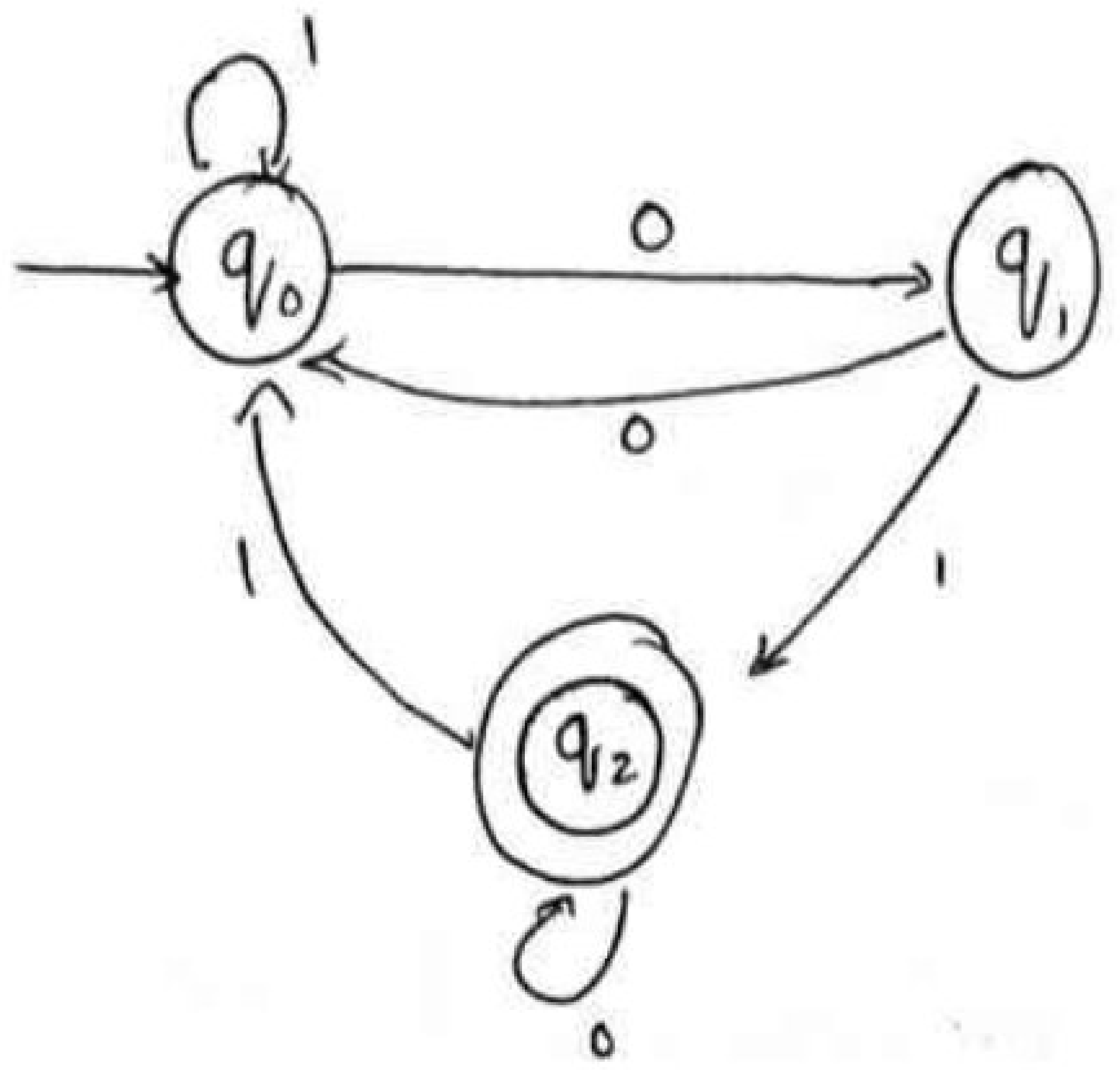
$F \to$ Final State $(F \subset q)$

-> Transition function (δ) :- Taking different inputs and producing different outputs.

-> Transition Table :- A Tabular format of different Transitions

-> Transition Diagram :- Diagramatic representation of different transitions.

⇒ Representation of Transition State and Transition Diagram



* Initial State has arrow and Final state has double circle

P.S	I/P	N.S
q_0	0	q_1
q_0	1	q_0
q_1	0	q_0
q_1	1	q_2
q_2	0	q_2
q_2	1	q_0

P.S	N.S 0	N.S 1
$\rightarrow q_0$	q_1	q_0
q_1	q_0	q_2
q_2	q_2	q_0

$$M = \Big\{ \underbrace{\{q_0, q_1, q_2\}}_{Q},\ \underbrace{\{0, 1\}}_{\Sigma},\ \underbrace{\begin{matrix} \delta(q_0,0) \Rightarrow q_1 & \delta(q_1,1) \rightarrow q_2 \\ \delta(q_0,1) \rightarrow q_0, & \delta(q_2,0) \rightarrow q_2, \\ \delta(q_1,0) \Rightarrow q_0, & \delta(q_2,1) \rightarrow q_0 \end{matrix}}_{\delta},\ \underbrace{q_0}_{q_0},\ \underbrace{q_2}_{F} \Big\}$$

⇒ Theory of Computation is divided as:-

① Automata Theory

* Stores '1' bit data
* Low Processing Speed

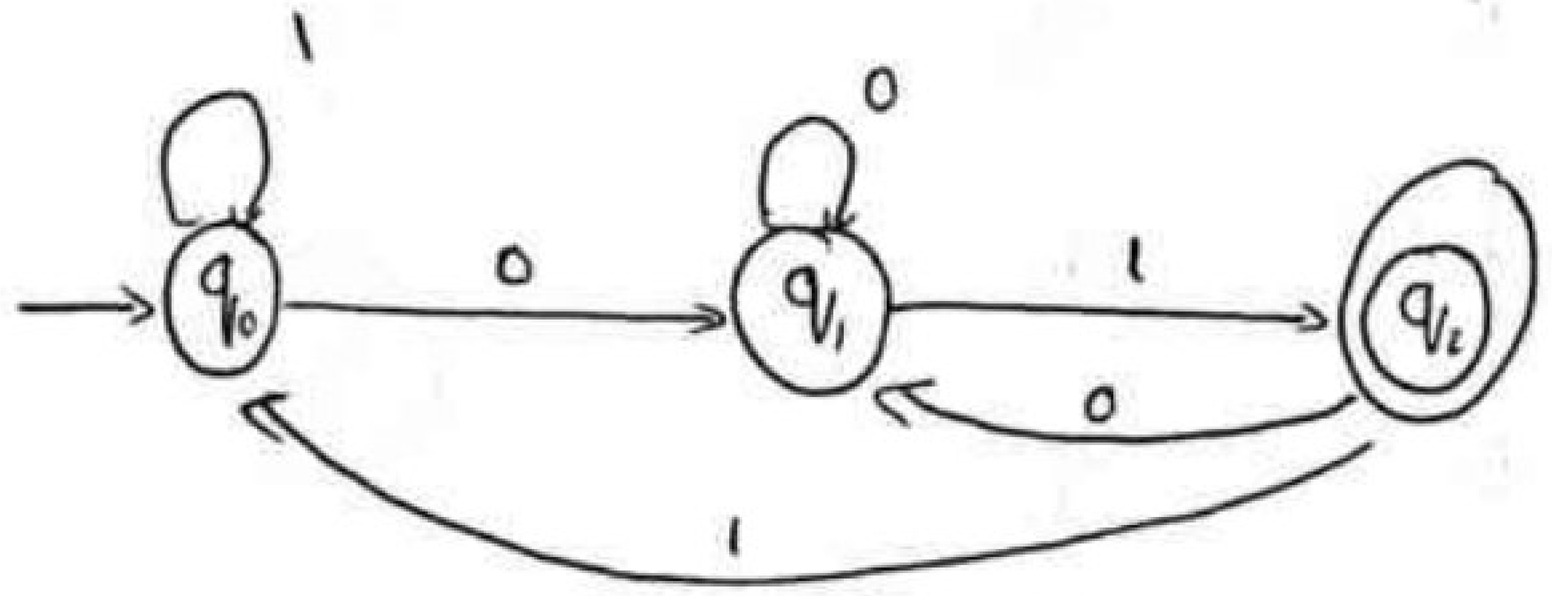
② Computability Theory:-

* Whether the Problem can be solved (or) not

③ Complexity Theory:-

* How much complexity can be added to machine

①) Draw the DFA for the language accepting strings ending with 01 over the alphabet $\Sigma = \{0, 1\}$



Note:- The outputs are not represented in the DFA Transition diagram.

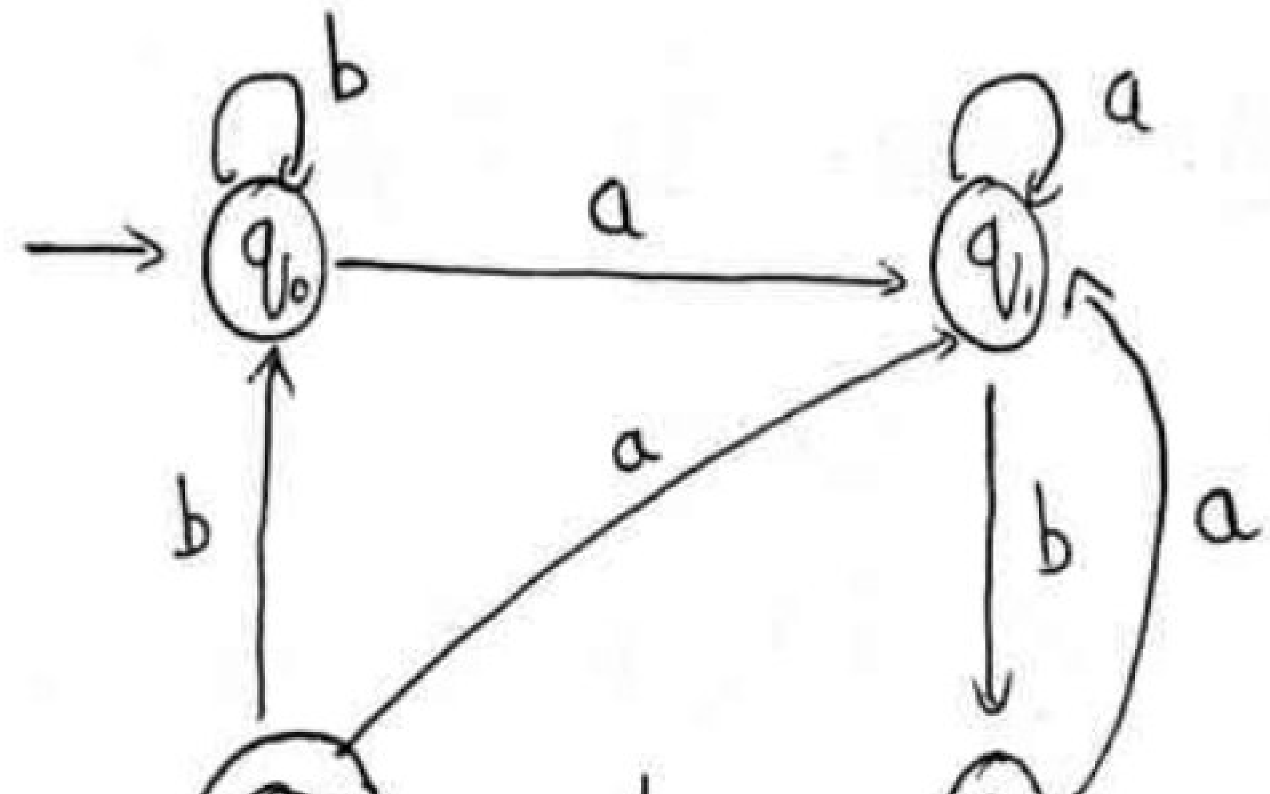
$$M = \left\{ \begin{array}{ccccc} Q & \Sigma & \delta & q_0 & F \\ \{q_0, q_1, q_2\}, & \{0,1\}, & \begin{array}{l} \delta(q_0,0) = q_1 \\ \delta(q_0,1) = q_0 \\ \delta(q_1,0) = q_1 \\ \delta(q_1,1) = q_2 \\ \delta(q_2,0) = q_1 \\ \delta(q_2,1) = q_0 \end{array} & , \; q_0 & , \; q_2 \end{array} \right\}$$

P.S	N.S	
	0	1
$\rightarrow q_0$	q_1	q_0
q_1	q_1	q_2
q_2	q_1	q_0

$$R = \{ (0+1)^* 01 \}$$

(2) Draw the DFA for the language accepting strings ending with 'abb' over the alphabet $\Sigma = \{a, b\}$.

The ending is abb, so we need 4 states
q_0, q_1, q_2, q_3



P.S	N.S	
	a	b
$\rightarrow q_0$	q_1	q_0
q_1	q_1	q_2
q_2	q_1	q_3
q_3	q_1	q_0

$M = \{ \overset{Q}{\{q_0, q_1, q_2, q_3\}}, \overset{\Sigma}{\{a, b\}}, \delta, q_0, \overset{F}{q_3} \}$

$R = \{(a+b)^* abb\}$

$\delta(q_0, a) = q_1$ $\qquad$ $\delta(q_2, a) = q_1$

$\delta(q_0, b) = q_0$ $\qquad$ $\delta(q_2, b) = q_3$

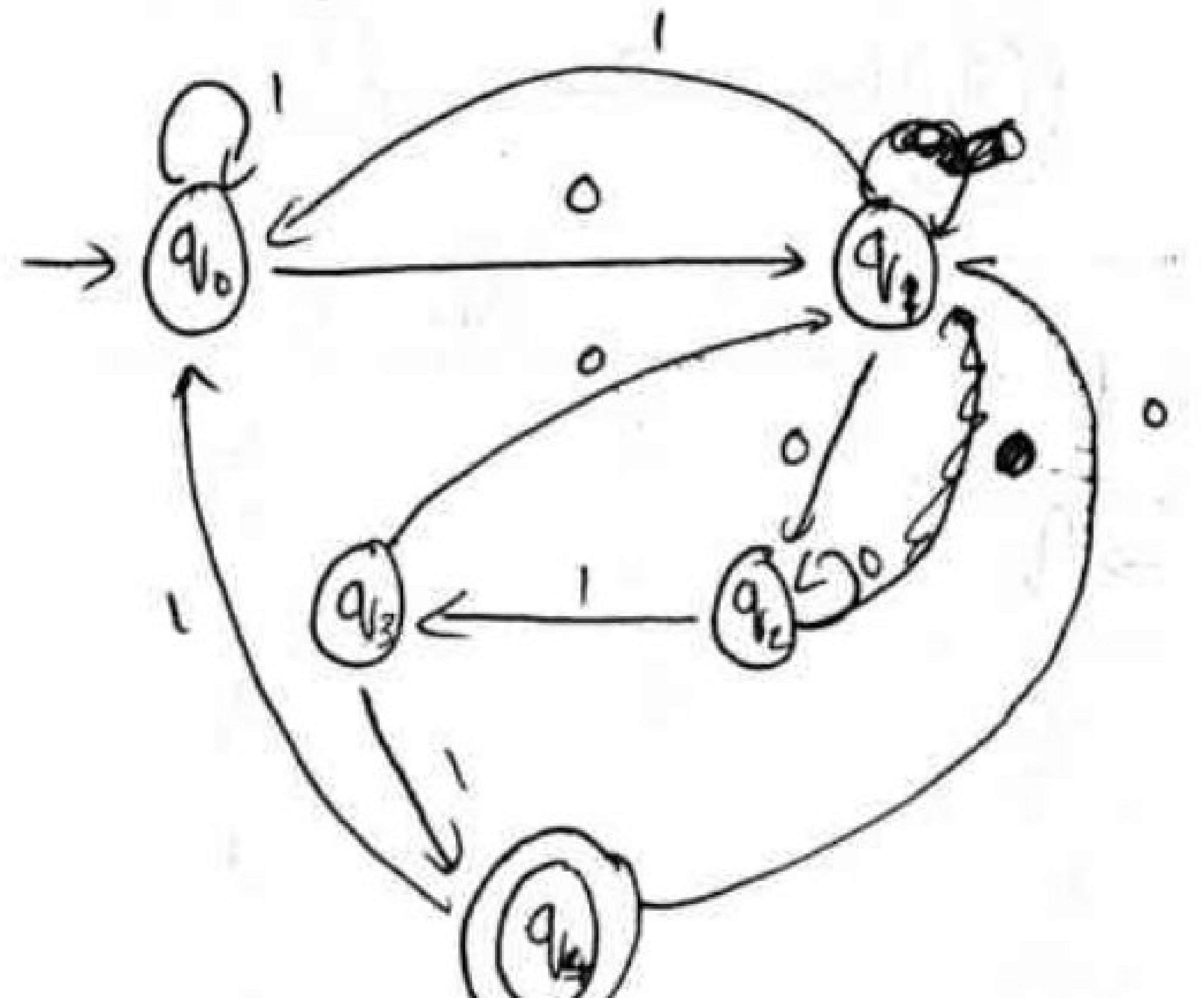
$\delta(q_1, a) = q_1$ $\qquad$ $\delta(q_3, a) = q_1$

$\delta(q_1, b) = q_2$ $\qquad$ $\delta(q_3, b) = q_0$

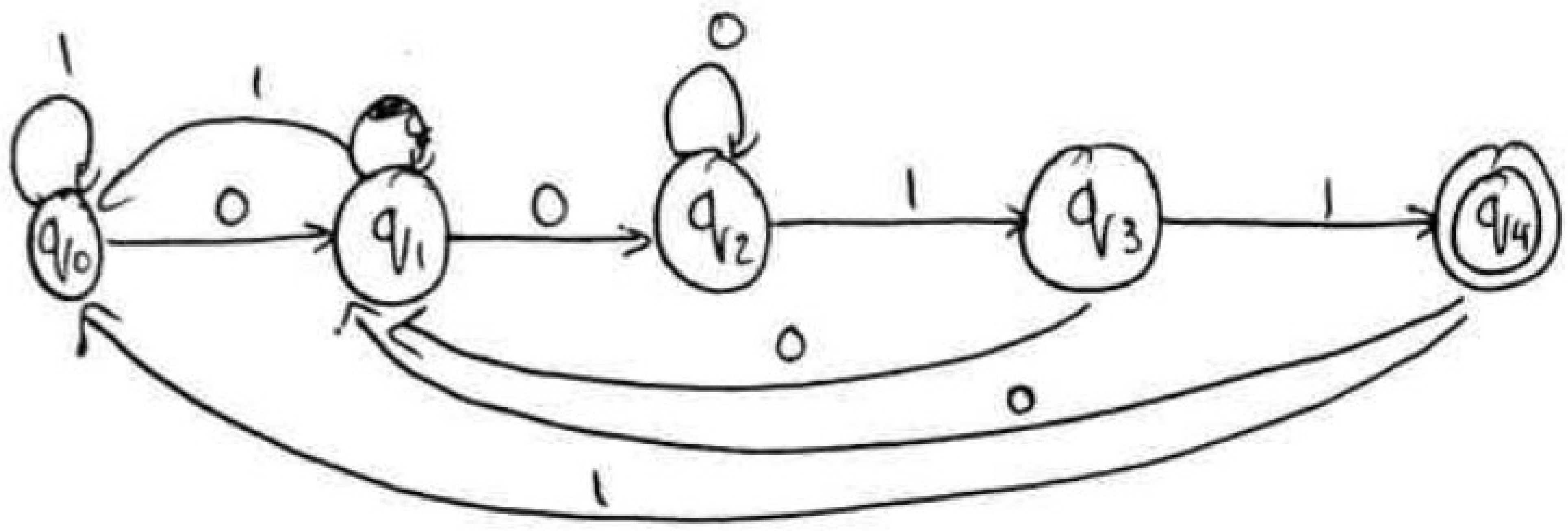
(3) Draw the DFA for the language accepting strings ending with 0011 over the alphabet $\Sigma = \{0, 1\}$

We require 5 states,

$\therefore Q = \{q_0, q_1, q_2, q_3, q_4\}$



P. S	N. S	
	0	1
$\rightarrow q_0$	q_1	q_0
q_1	q_2	q_0
q_2	q_2	q_3
q_3	q_1	q_4
q_4	q_1	q_0



$$M = \left\{ \overset{Q}{\{q_0, q_1, q_2, q_3, q_4\}},\ \overset{\Sigma}{\{0,1\}},\ \delta,\ q_0,\ \overset{F}{q_4} \right\}$$

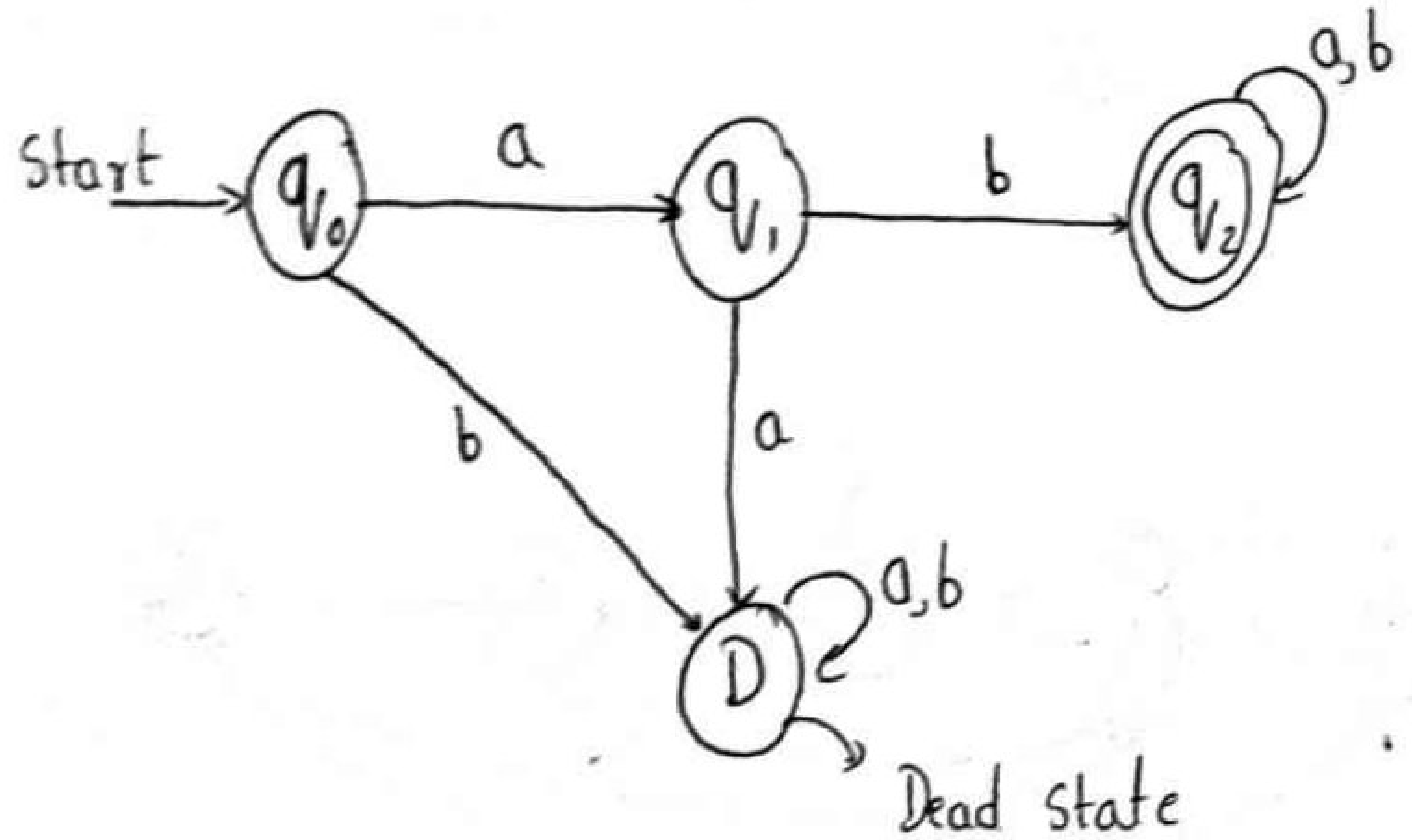
$$R = \{ (0+1)^* 0011 \}$$

④ Draw the DFA for the language accepting string starting with 'ab' over the alphabet $\Sigma = \{a, b\}$.

Regular Expression,

$$R = \{ab(a+b)^*\}$$

There are 2 bits so we need four states



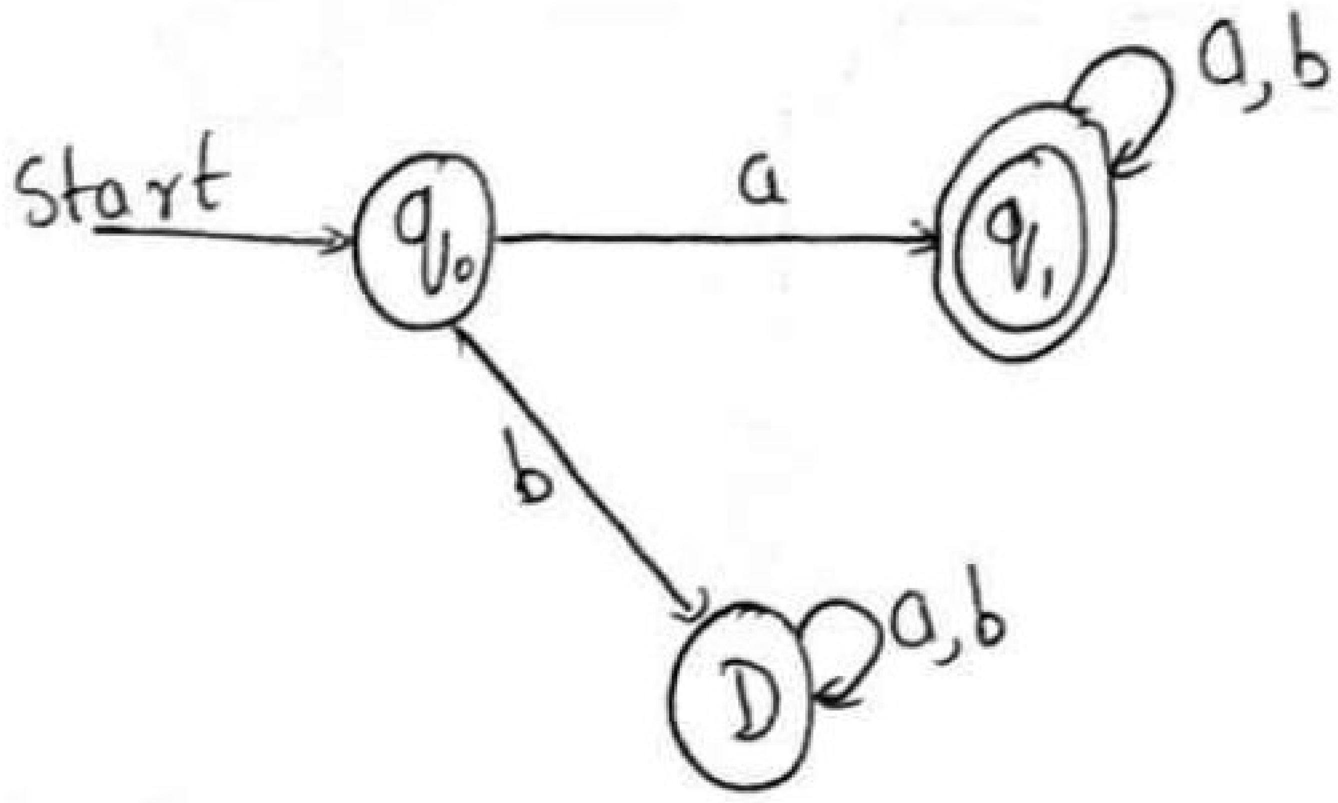
P.S	N.S a	N.S b
$\rightarrow q_0$	q_1	D
q_1	D	q_2
q_2^*	q_2	q_2

(5) Draw the DFA for the language accepting strings Starting with 'a' for the input alphabet, $\Sigma = \{a, b\}$

Regular Expression,

$$R = \{a(a+b)^*\}$$

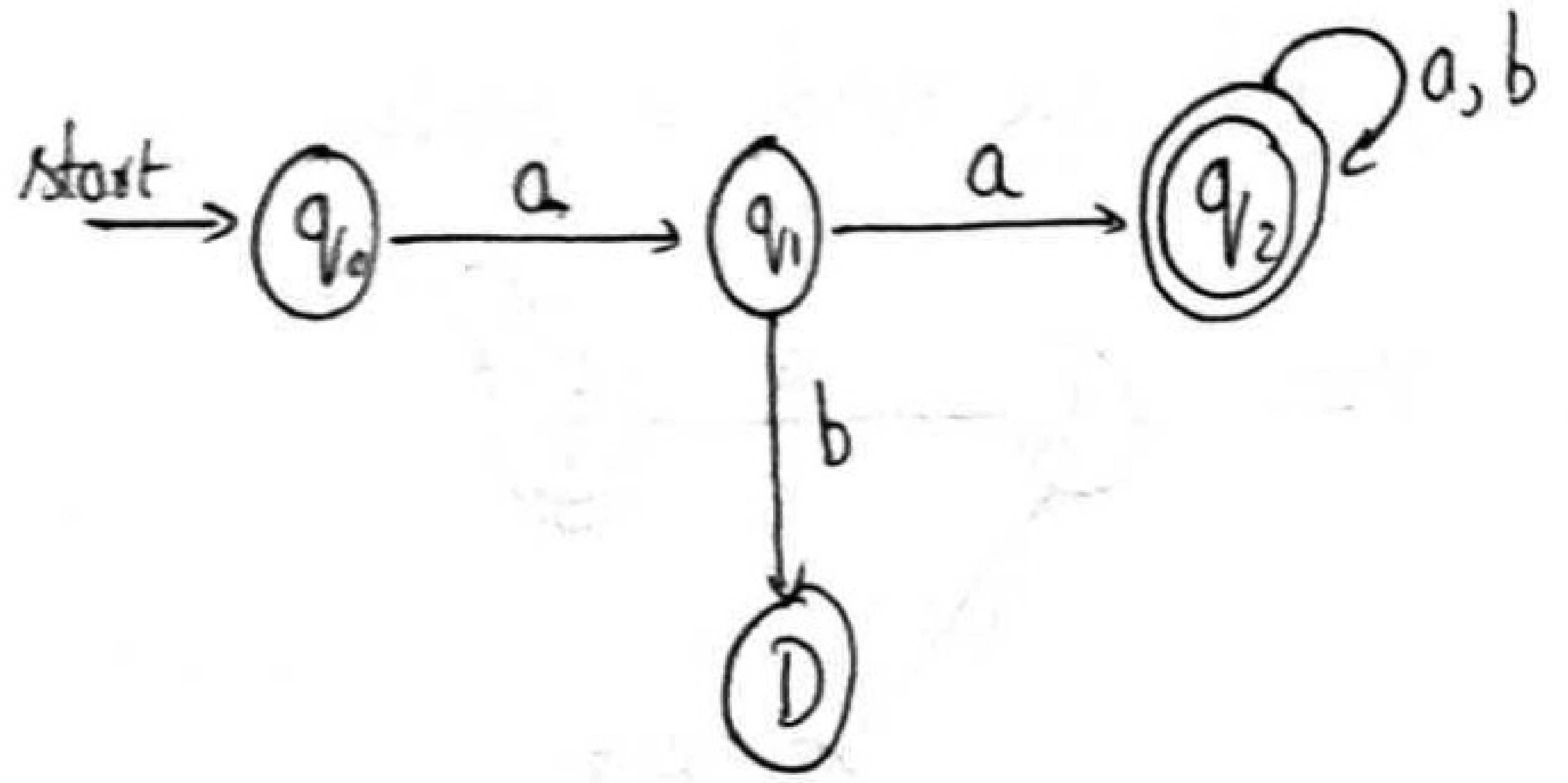
For '1' bit we need 3 states

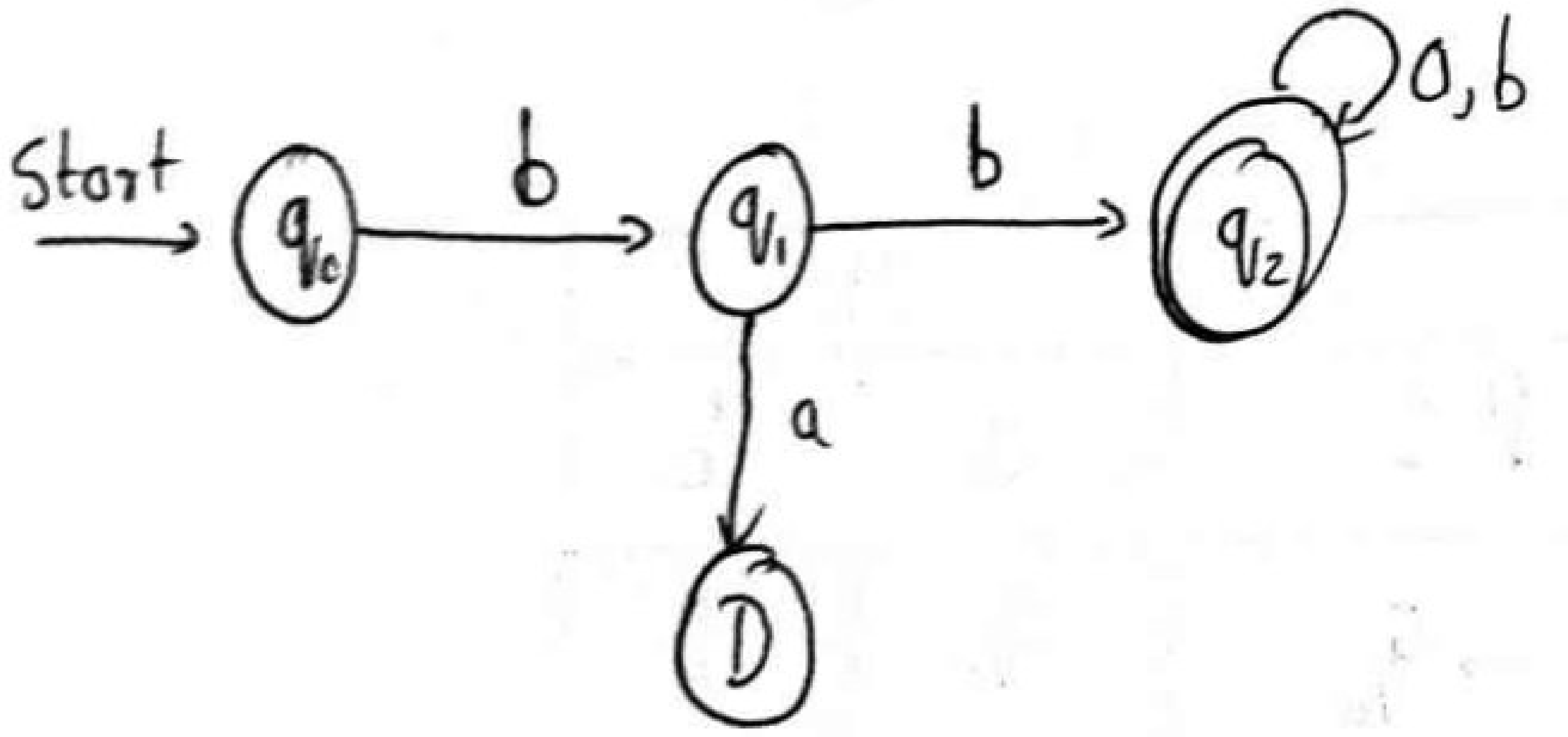


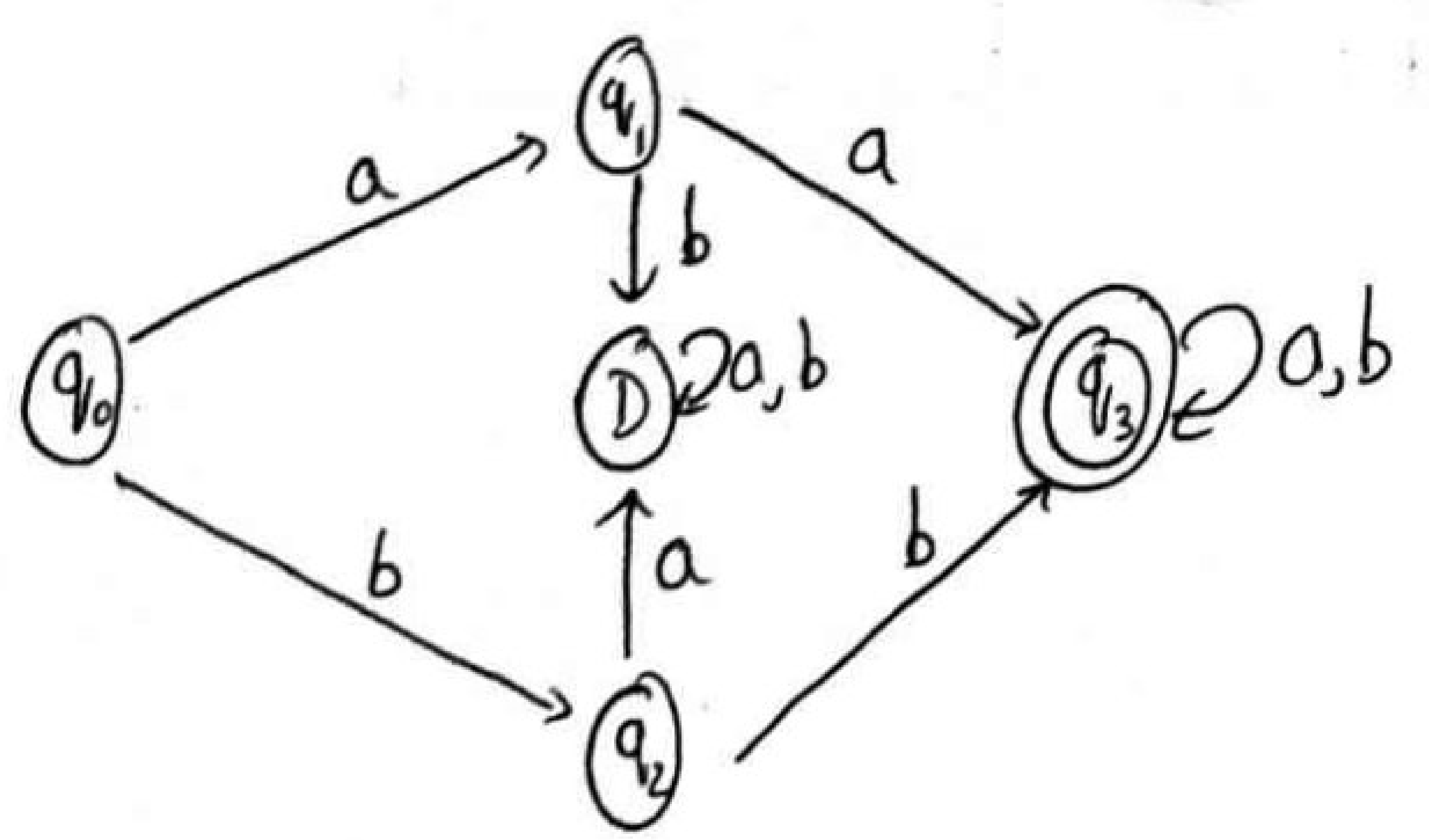
	N.S	
P.S	a	b
$\rightarrow q_0$	q_1	D
$*q_1$	q_1	q_1

⑥ Construct a DFA that accepts a language over the alphabet $\Sigma = \{a, b\}$ such that 'L' is a set of all strings starting with aa or bb

Total no of states = 4







$R = \{ (aa+bb)^*$

	N. S	
P. S	a	b
q_0	q_1	q_2
q_1	q_3	D
q_2	D	q_3
q_3	q_3	q_3

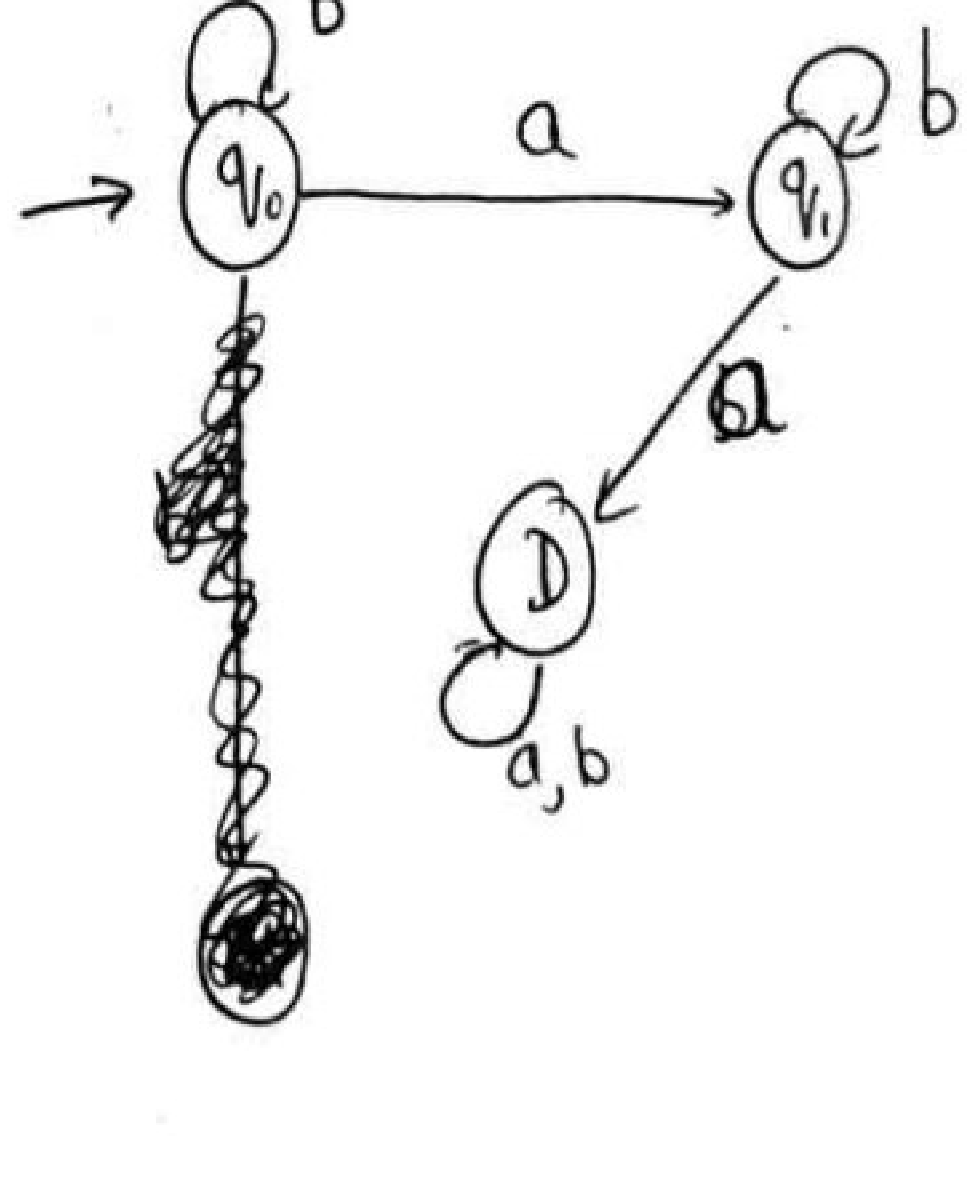
(7) Design the DFA that accepts the language 'L' over the alphabet $\Sigma = \{a,b\}$

(i) exactly one 'a'

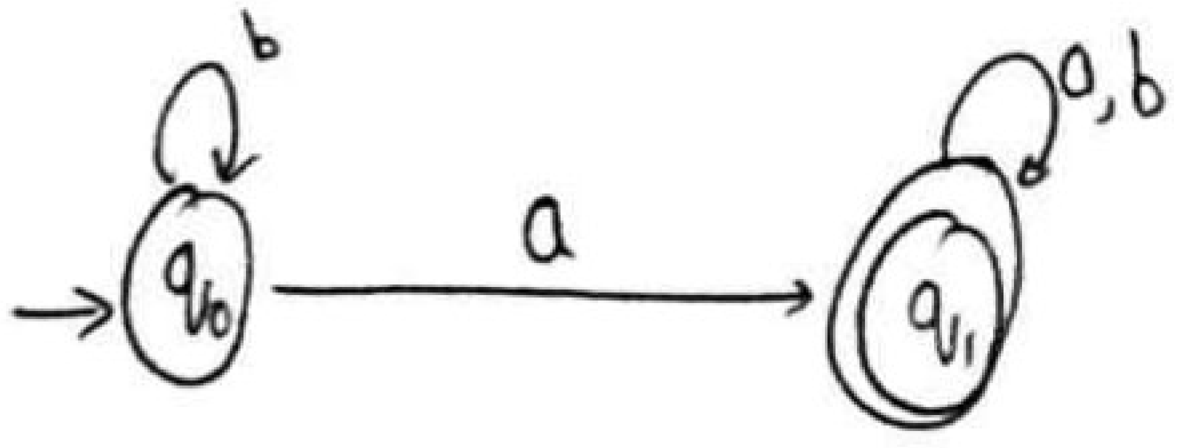
(ii) atleast one 'a'

(iii) atmost one 'a'

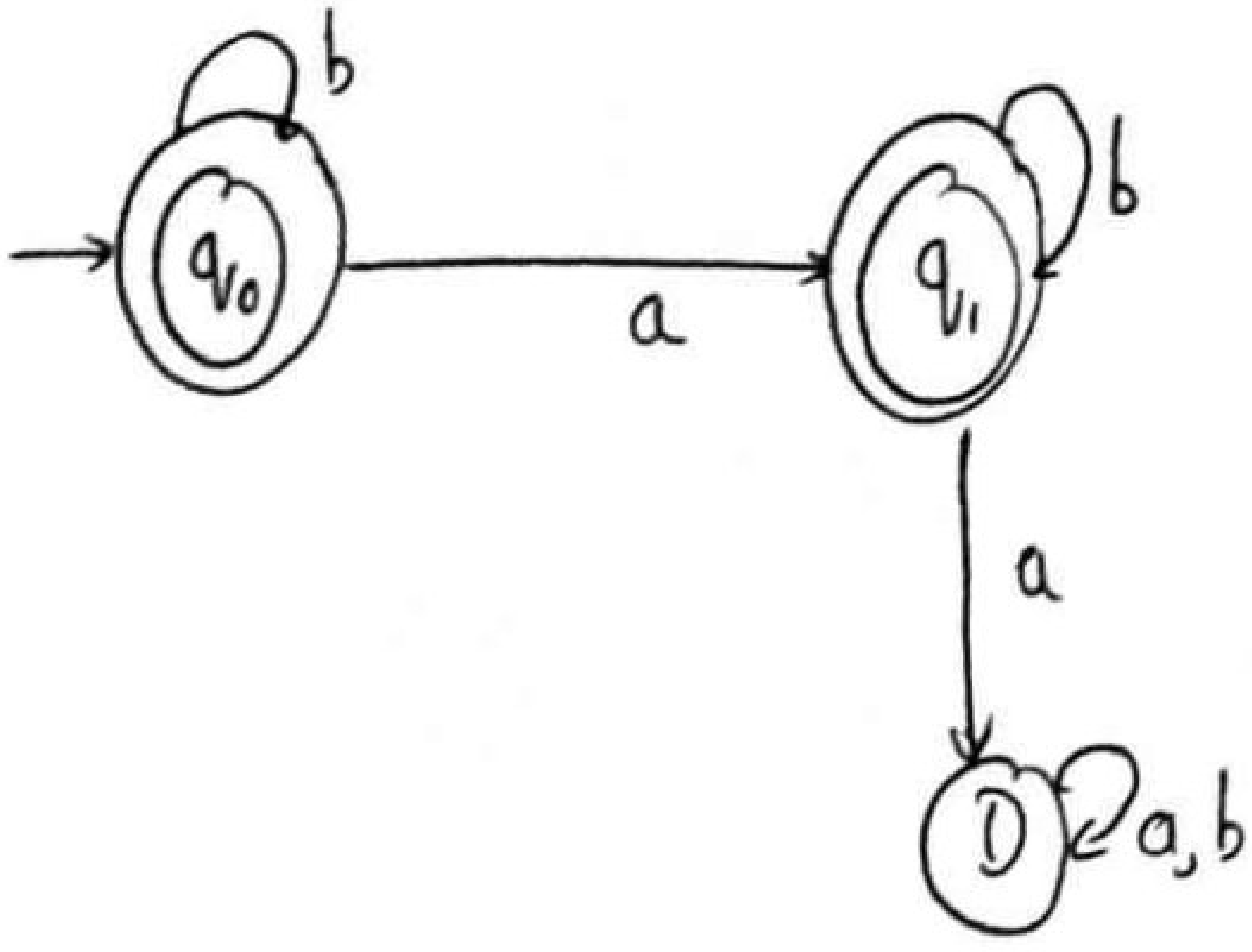
(i)



(ii)



(iii)

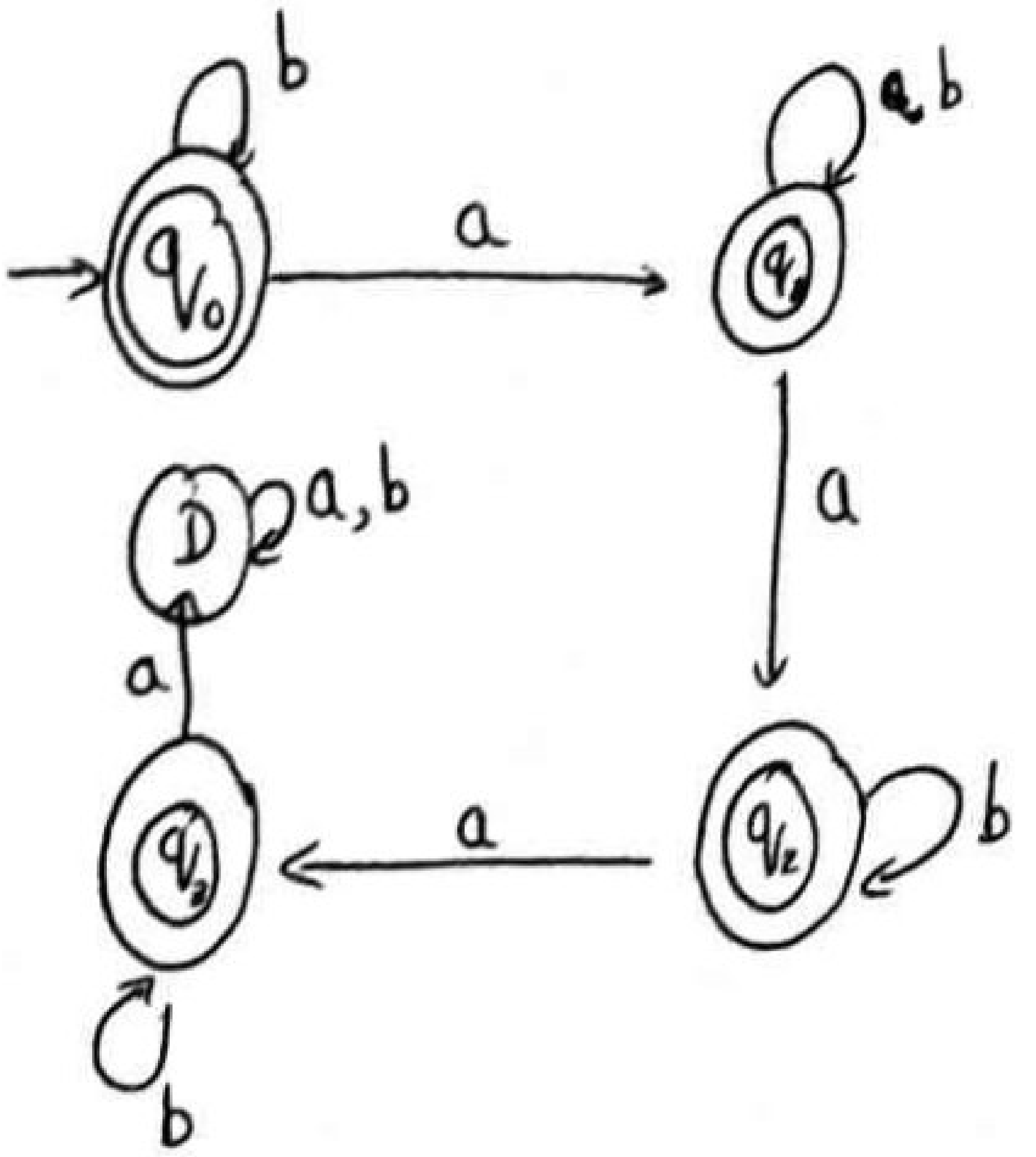


(7) Design a DFA that accepts a language 'L' over the alphabet $\Sigma = \{a, b\}$ such that 'L' is a set of string

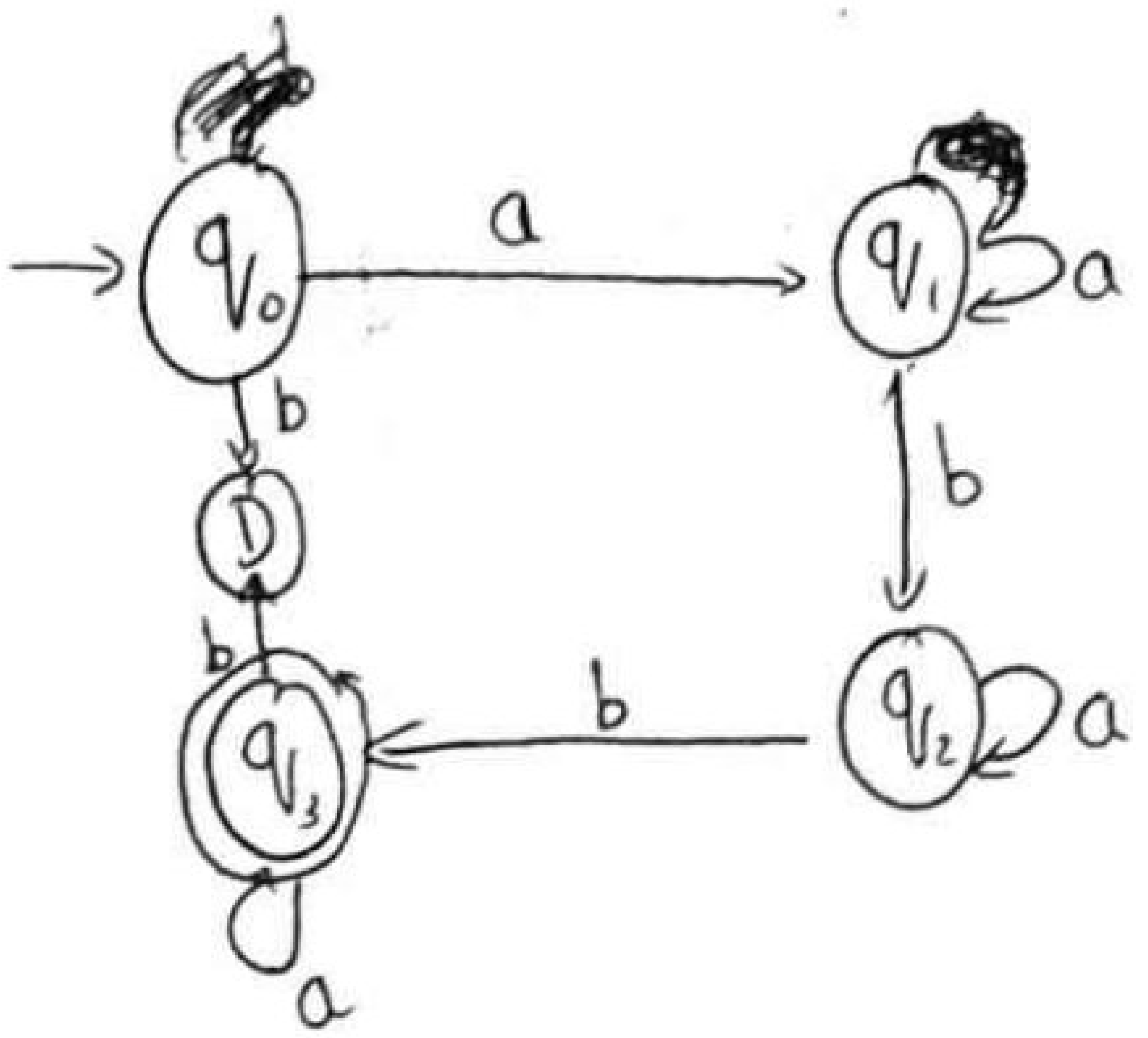
(i) no more than 3 a

(ii) atleast a & exactly two b's

(i)



(ii)



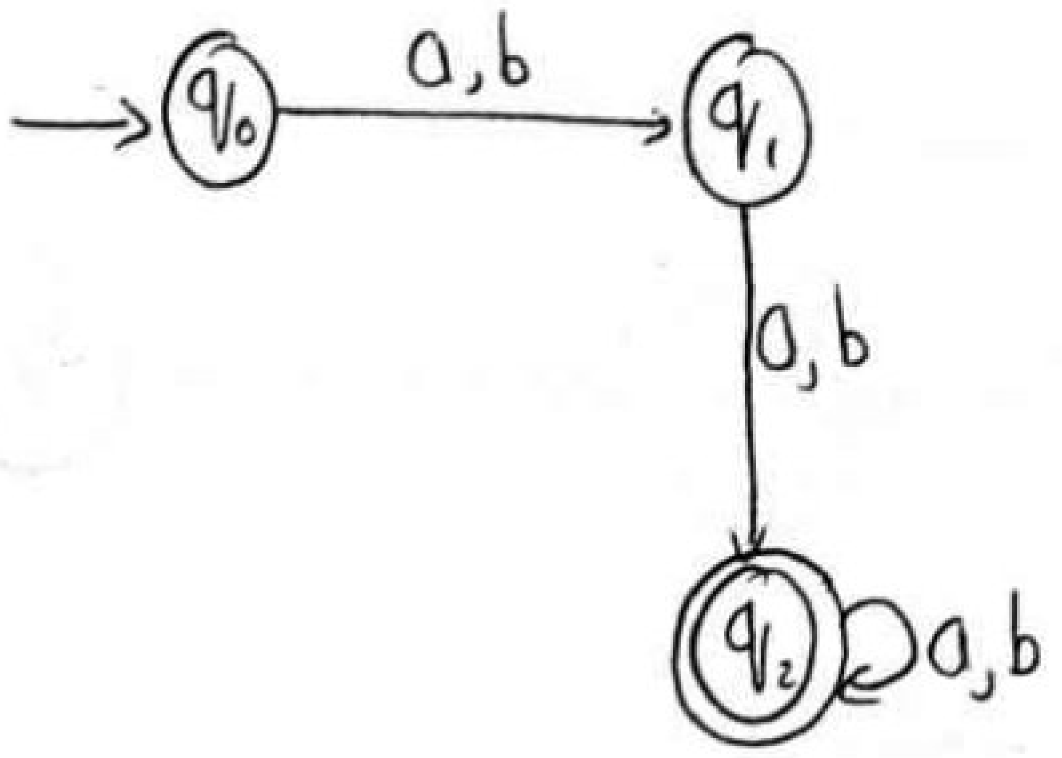
8 Construct a DFA that accepts a language 'L' over the ~~languag~~ alphabet $\Sigma = \{a, b\}$ such that

(i) length of string is atleast 2

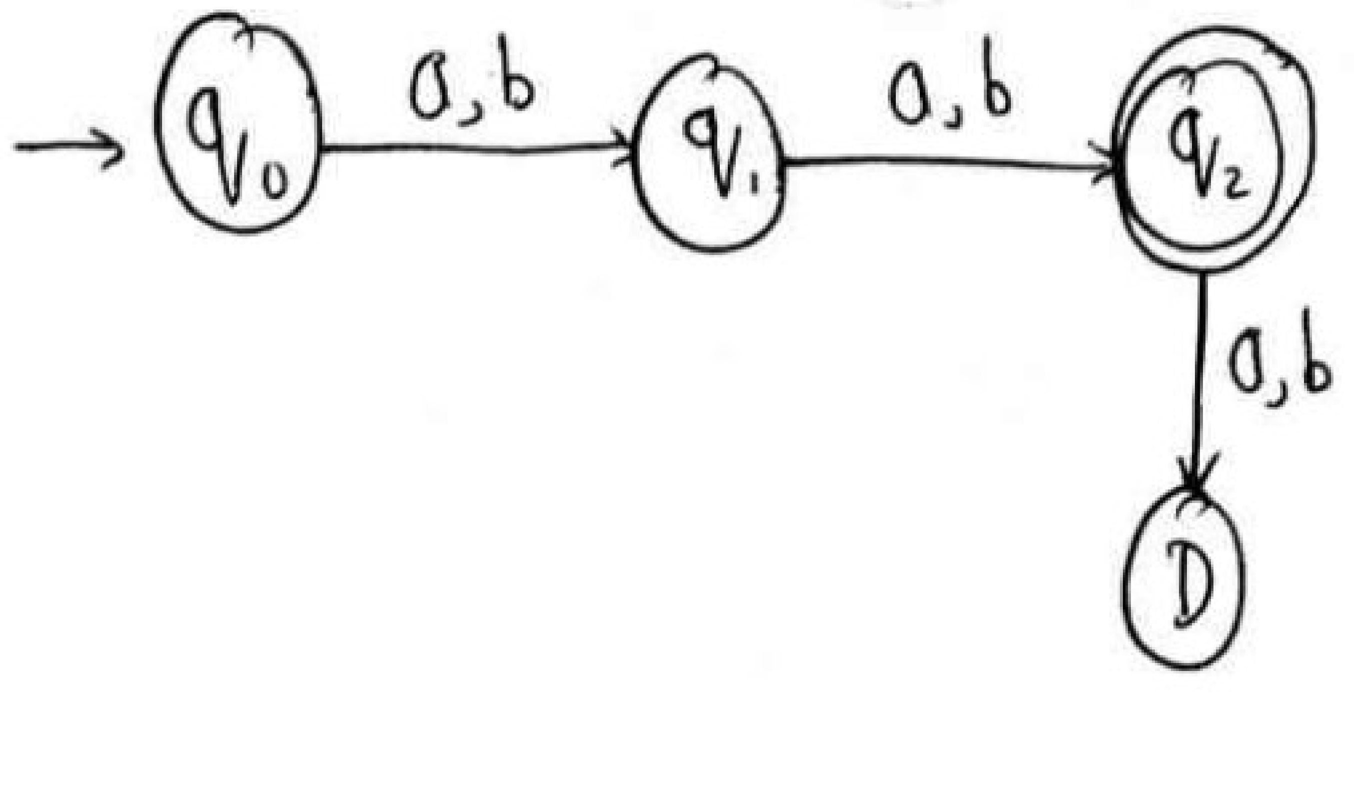
(ii) Length of string is exactly 2

(iii) Length of String is atmost 2

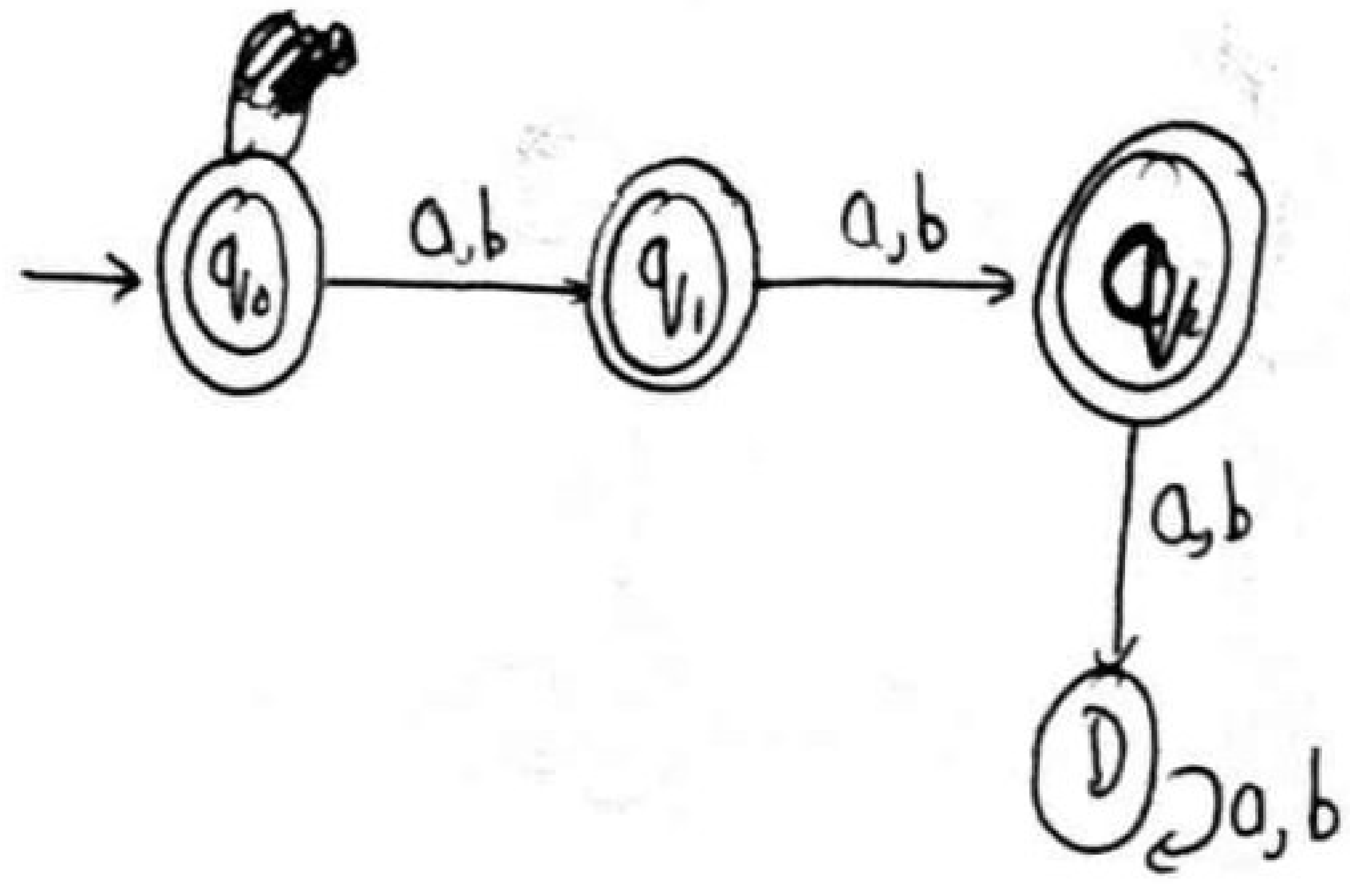
(i)



(ii)



(iii)

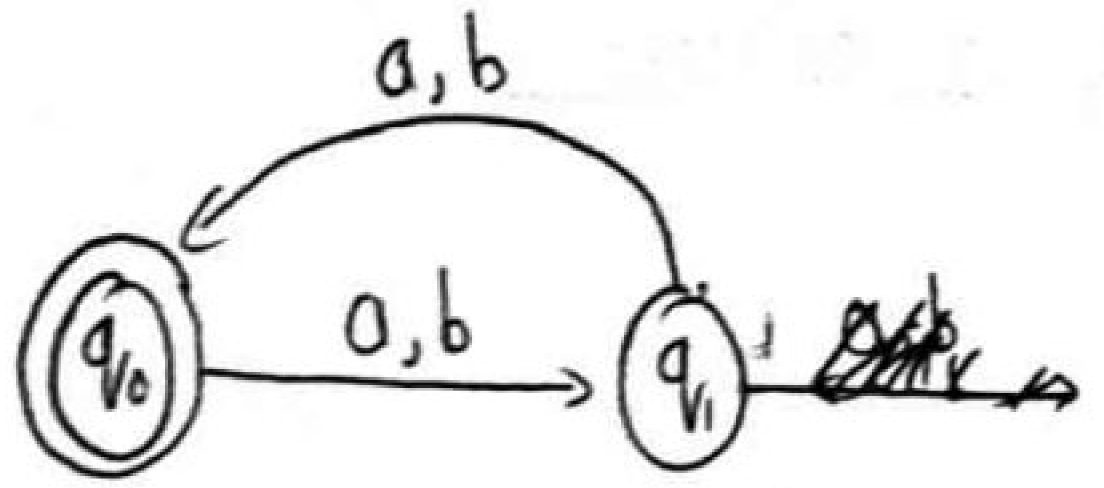


(9) Construct a DFA that accepts a string over input alphabet $\Sigma = \{a,b\}$ such that

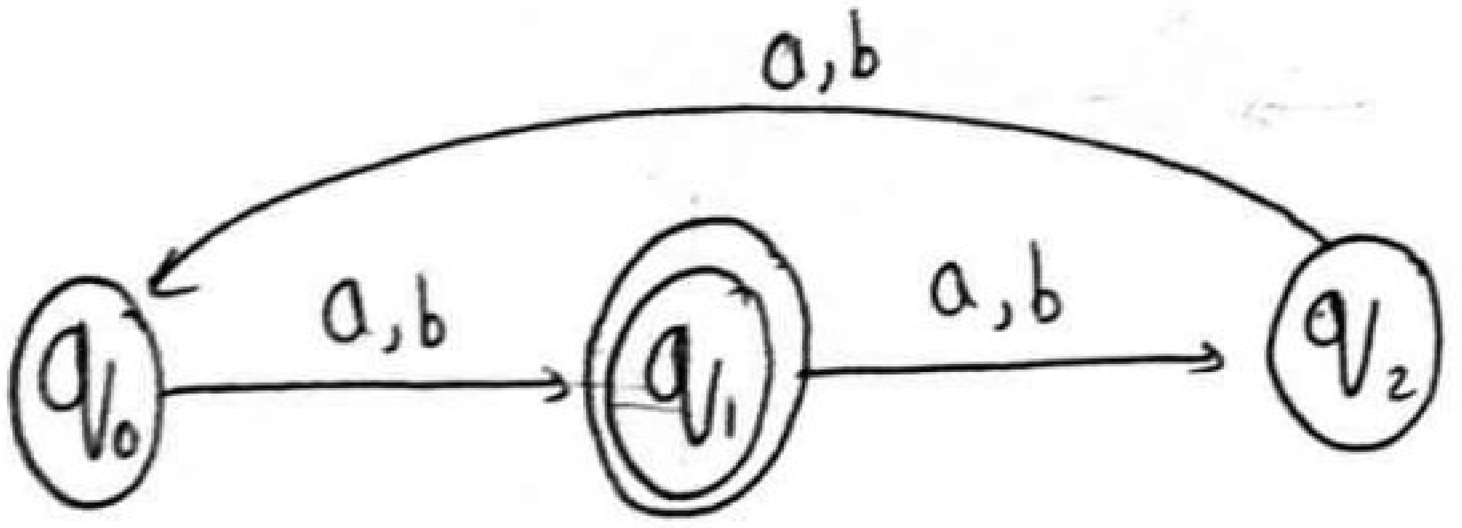
(i) $|w| \bmod 2 = 0$ (aa, abab, ...)

(ii) $|w| \bmod 3 = 1$ (iii) $|w| \bmod 2 = 1$

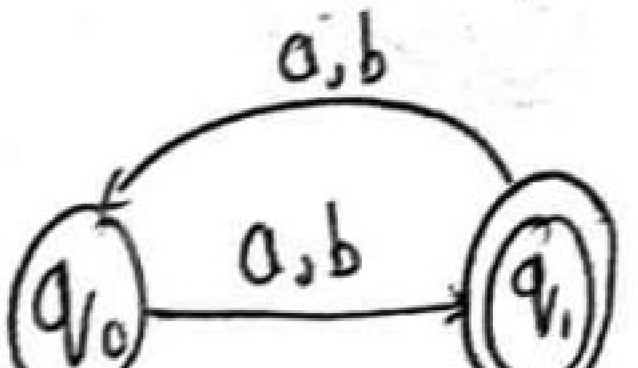
(i)



(ii)



(iii)



⇒ Non-Deterministic Finite Automata (NFA) :-

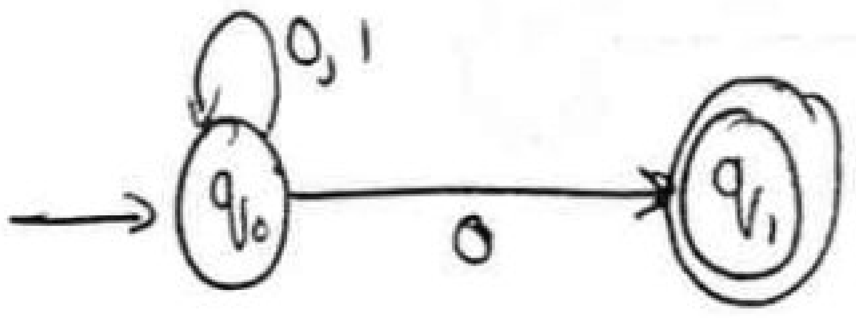
A NFA is defined by quintuple

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

where, $\delta : Q \times \Sigma \rightarrow 2^Q$

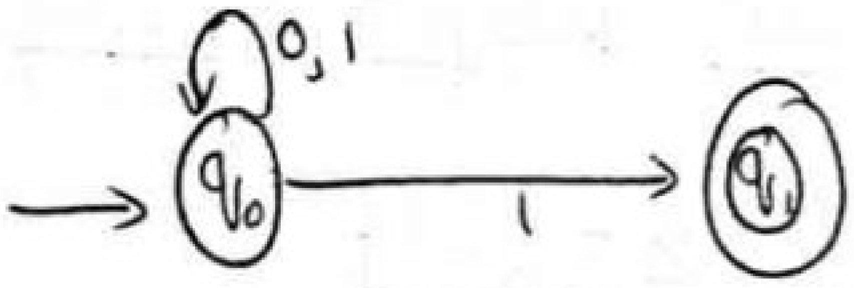
① Construct an NFA that accepts all set of strings ending with '0' over an input alphabet $\Sigma = \{0, 1\}$.

$$R = \{(0+1)^* 0\}$$

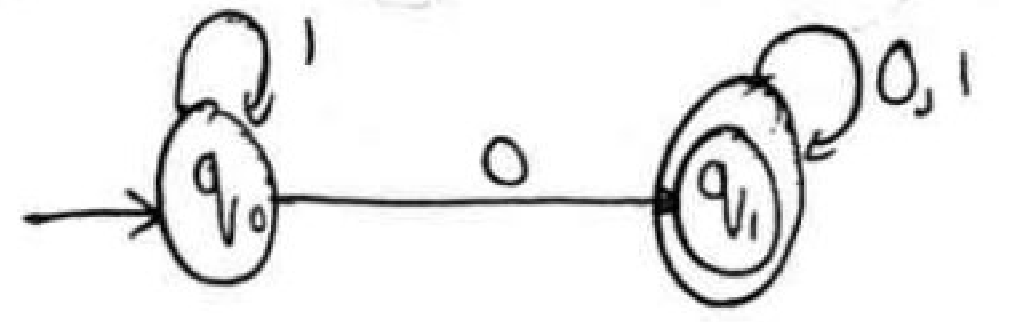


② Construct an NFA for following cases :-

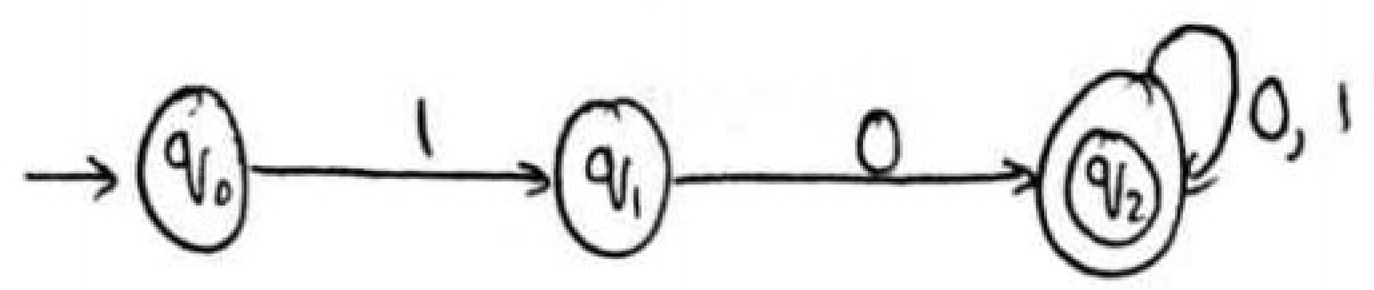
(i) L_1 = Set of all Strings ending with '1'



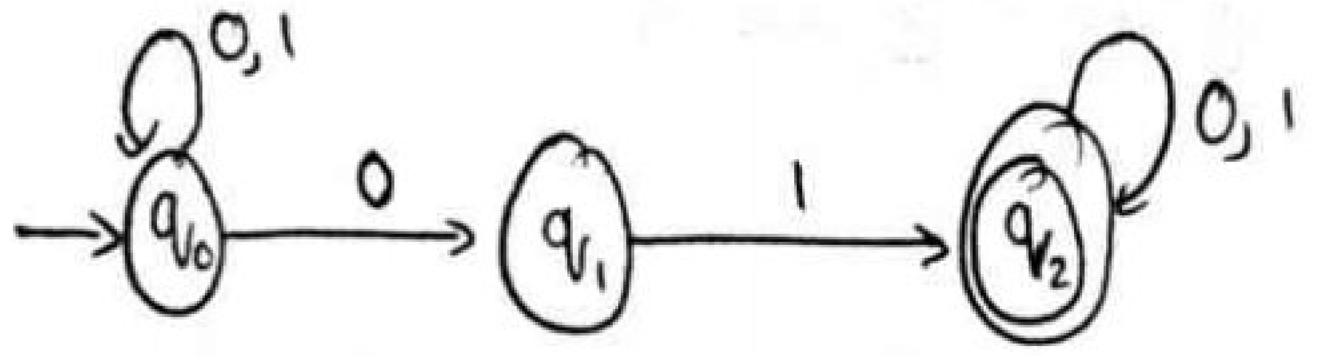
(ii) L_2 = Set of all strings that contain '0'



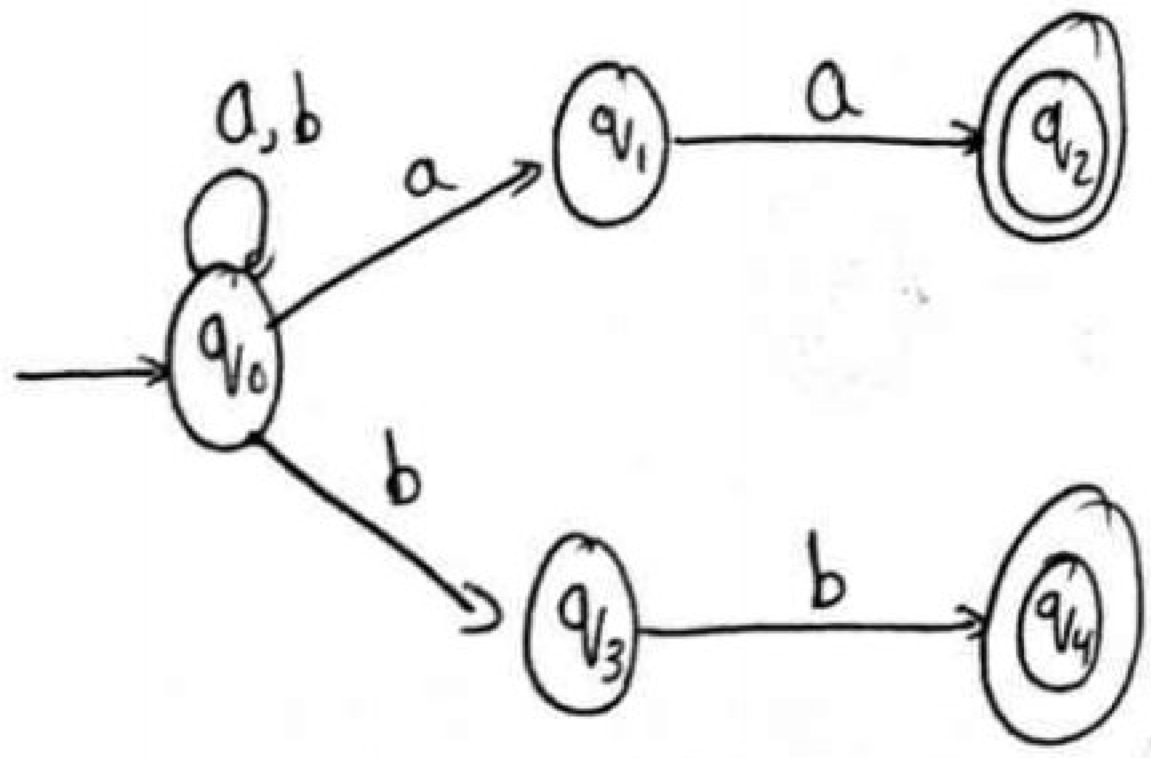
(iii) L_3 = Set of all String that starts with 10



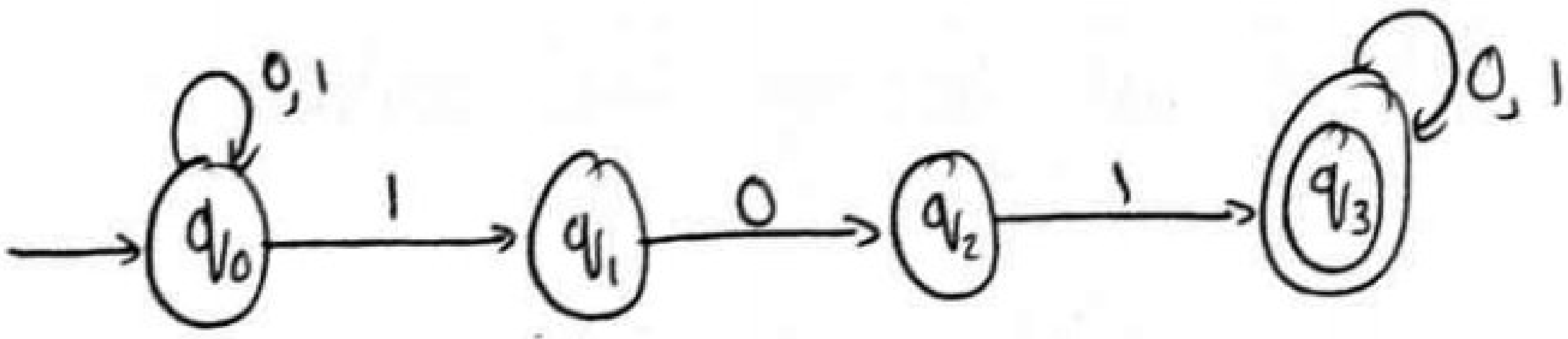
(iv) L_4 = Set of all Strings that contain 01



(3) Construct an NFA that accepts Strings ending with aa or bb



(4) Construct an NFA that accepts Strings containg 101 as Substring over alphabet $\Sigma = \{0, 1\}$

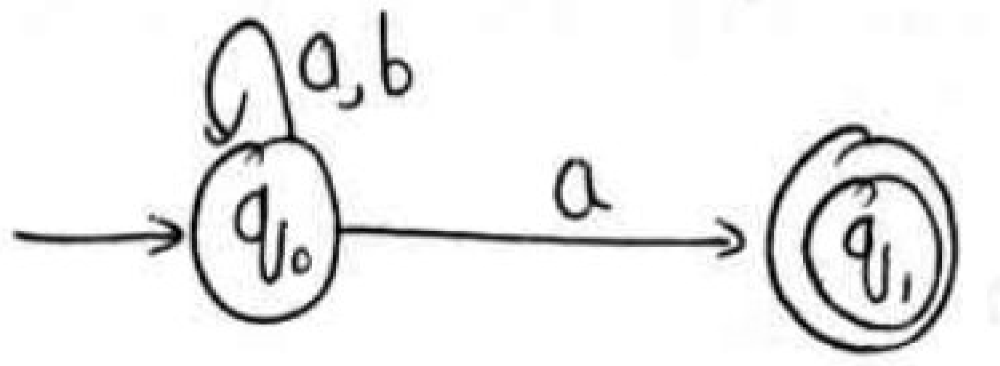


⇒ Conversion of NFA to DFA :-

① Convert from NFA to DFA, the language is set of all strings over $\Sigma = \{a, b\}$ that ends with 'a'.

→ Subset Construction Method :-

The NFA is



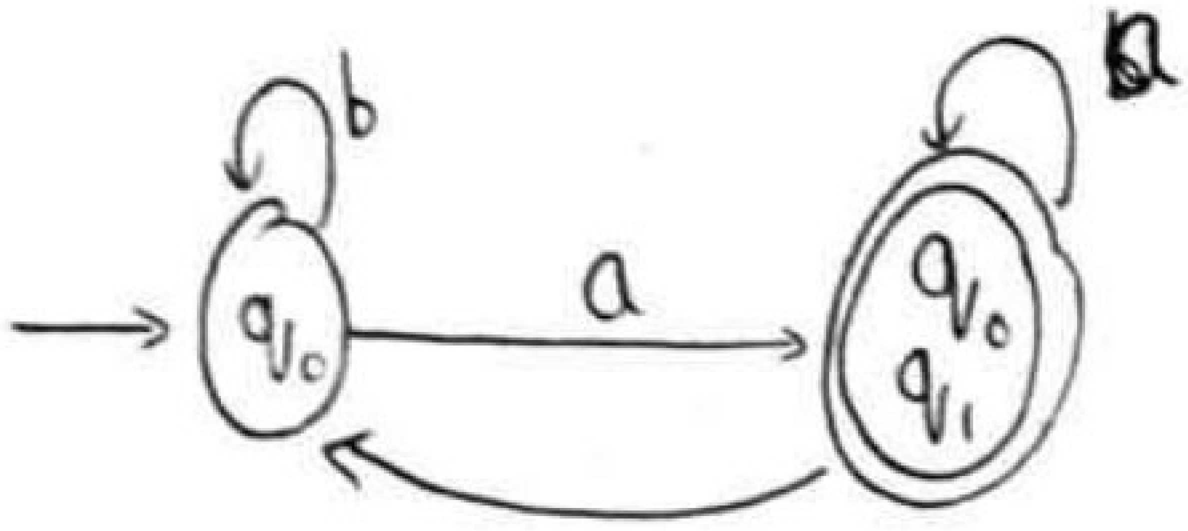
Transition Table :-

	a	b
$\rightarrow q_0$	$[q_0\, q_1]$	q_0
q_1	ϕ	ϕ

⇓ Considering q_0, q_1 as single state q_0q_1

	a	b
$\rightarrow q_0$	$[q_0 q_1]$	q_0
q_0q_1	$[q_0 q_1]$	q_0

∴ The DFA is



② Construct a DFA equivalent Machine

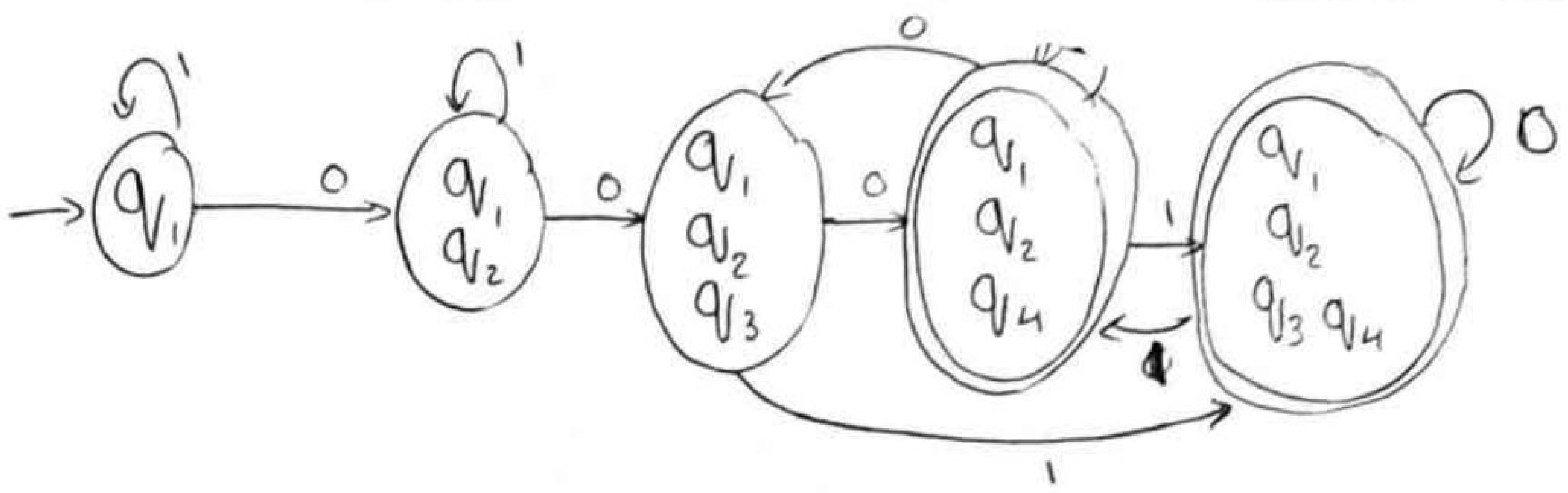
$M = (\{q_1, q_2, q_3, q_4\}, \{0, 1\}, \delta, q_1, q_4)$

where, δ is given as

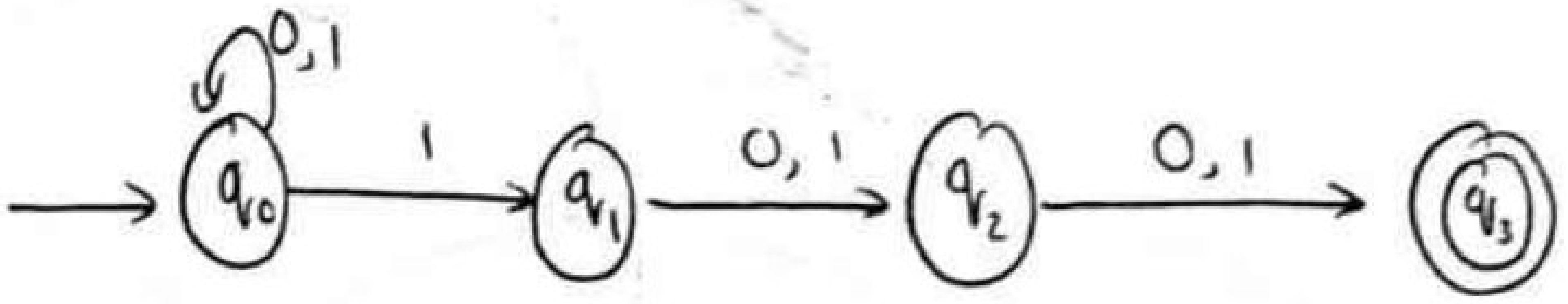
	0	1
$\rightarrow q_1$	$q_1 q_2$	q_1
q_2	q_3	q_2
q_3	q_4	q_4
$* q_4$	—	q_4

⇓

	0	1
$\rightarrow q_1$	$[q_1 q_2]$	q_1
$q_1 q_2$	$[q_1 q_2 q_3]$	$[q_1 q_2]$
$q_1 q_2 q_3$	$[q_1 q_2 q_3 q_4]$	$[q_1 q_2 q_4]$
$* q_1 q_2 q_3 q_4$	$[q_1 q_2 q_3 q_4]$	$[q_1 q_2 q_4]$
$* q_1 q_2 q_4$	$[q_1 q_2 q_3 q_4]$	$[q_1 q_2 q_4]$



③ Convert NFA to equivalent DFA for the transition Diagram shown below :-

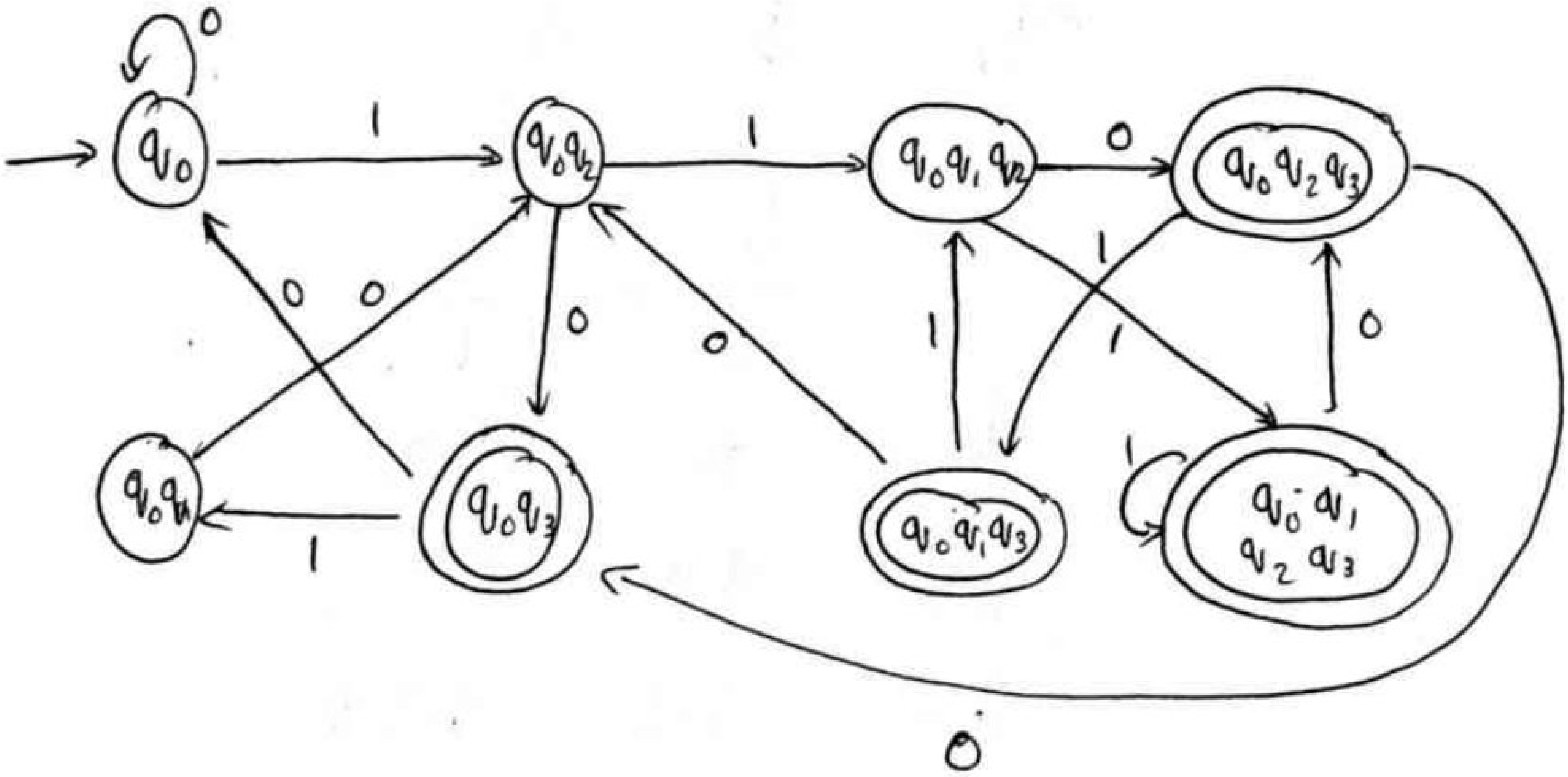


	0	1
$\rightarrow q_0$	q_0	$[q_0, q_1]$
q_1	q_2	q_2
q_2	q_3	q_3
$*q_3$	ϕ	ϕ

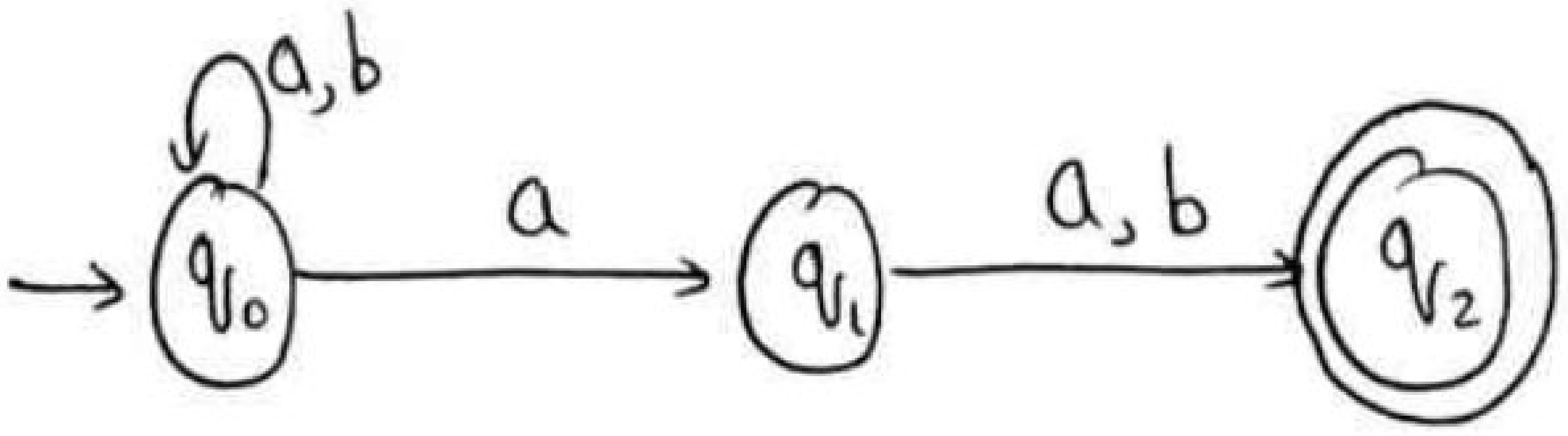
⇓

	0	1
q_0	q_0	$q_0 q_1$
$q_0 q_1$	$q_0 q_2$	$q_0 q_1 q_2$
$q_0 q_2$	$q_0 q_3$	$q_0 q_1 q_3$

	0	1
* $q_0 q_3$	q_0	$q_0 q_1$
$q_0 q_1 q_2$	$q_0 q_2 q_3$	$q_0 q_1 q_2 q_3$
* $q_0 q_1 q_3$	$q_0 q_3$	$q_0 q_1 q_2$
* $q_0 q_2 q_3$	$q_0 q_3$	$q_0 q_1 q_3$
* $q_0 q_1 q_2 q_3$	$q_0 q_2 q_3$	$q_0 q_1 q_2 q_3$



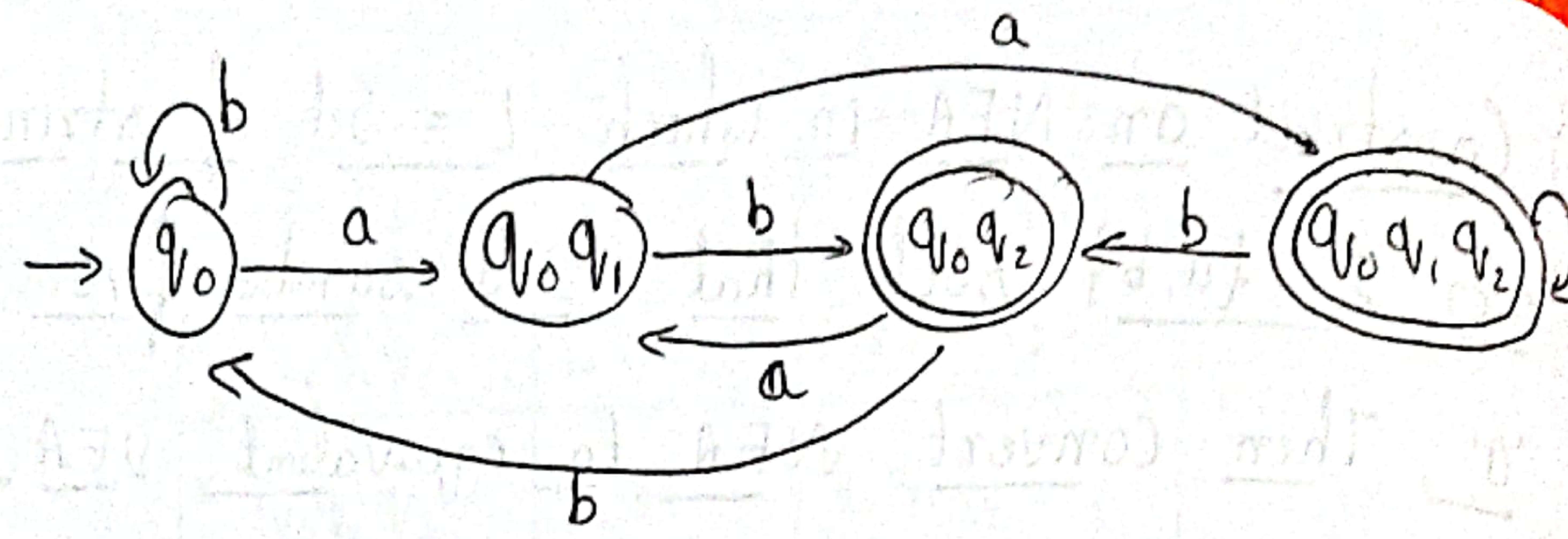
(4) Construct an NFA in which L = Set of strings over $\Sigma = \{a, b\}$ such that 2'nd symbol from RHS is 'a', Then convert NFA to equivalent DFA.



Transition Table :-

	a	b
$\rightarrow q_0$	$[q_0\, q_1]$	q_0
q_1	q_2	q_2
* q_2	ϕ	ϕ

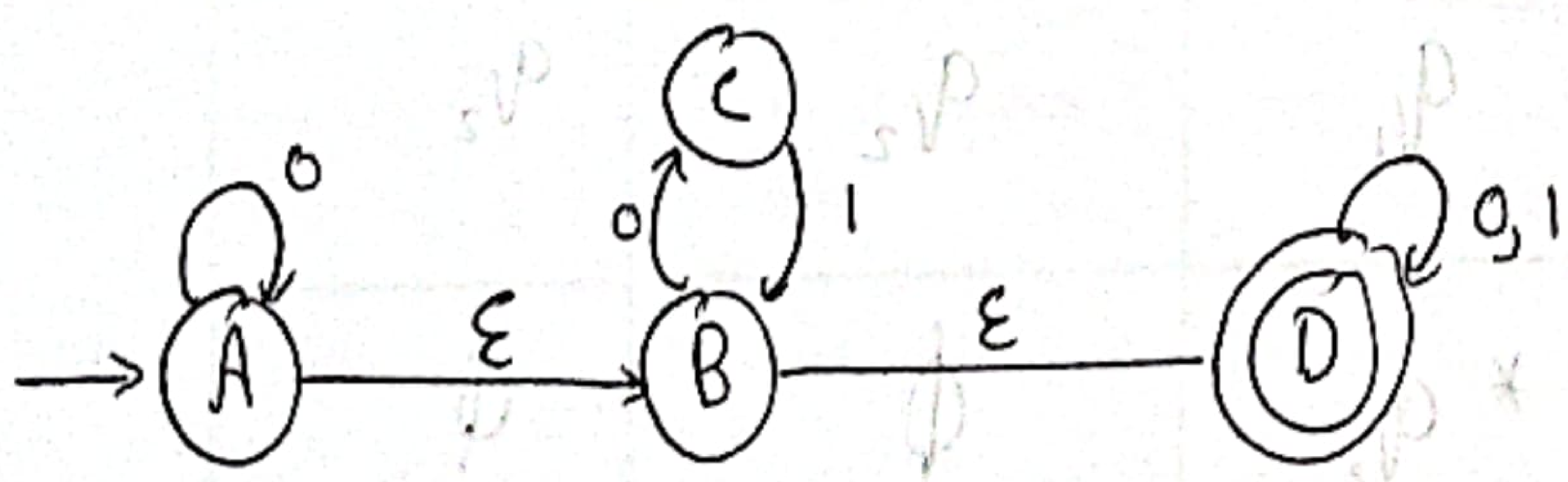
	a	b
$\rightarrow q_0$	$[q_0\, q_1]$	q_0
$q_0 q_1$	$[q_0 q_1 q_2]$	$q_0 q_2$
* $q_0 q_2$	$[q_0 q_1]$	q_0
* $q_0 q_1 q_2$	$[q_0 q_1 q_2]$	$[q_0 q_2]$



⇒ ε - NFA to NFA Conversion :-

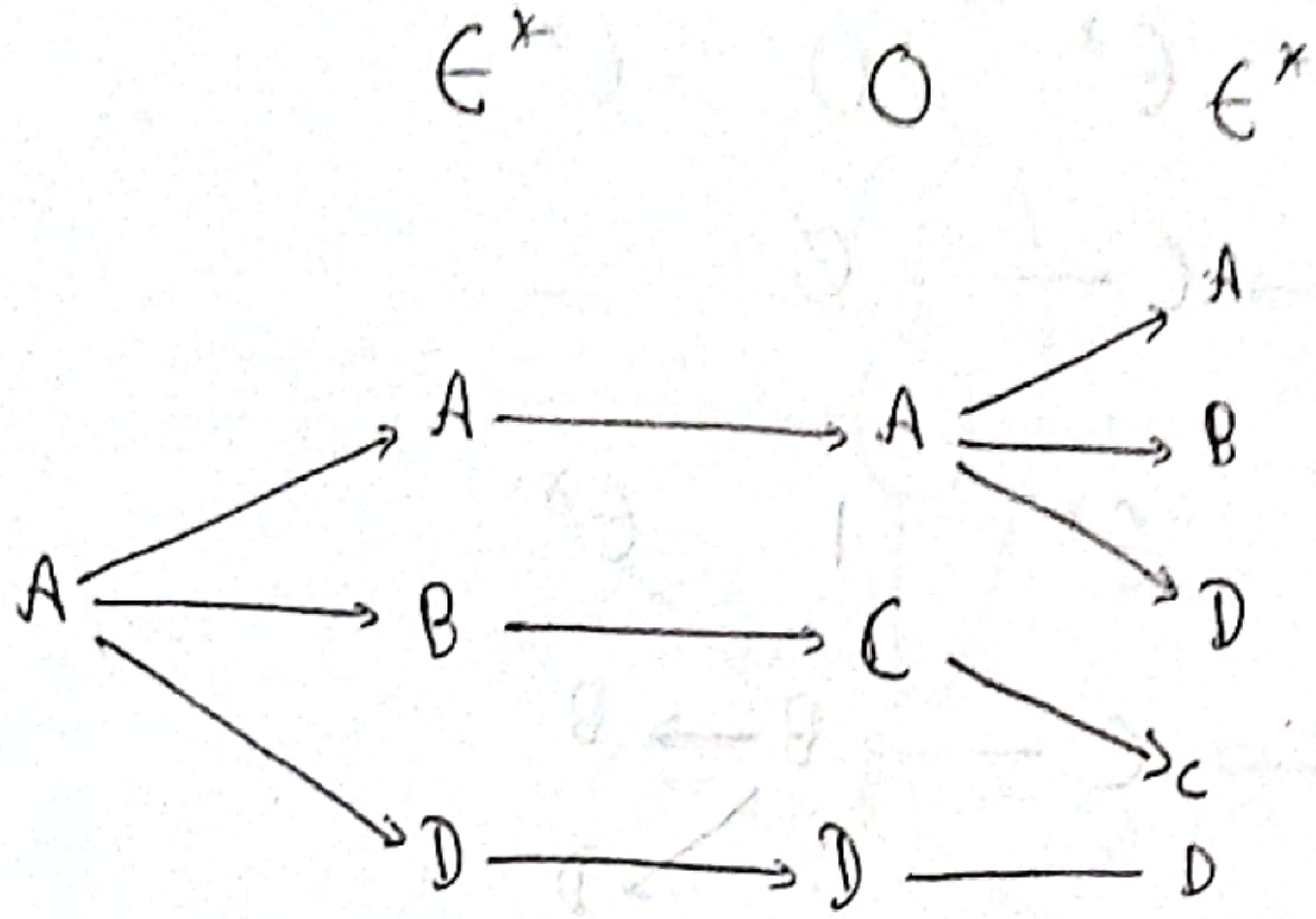
ε-NFA → Without reading any character it will go to next state.

① Convert from ε-NFA to NFA :-

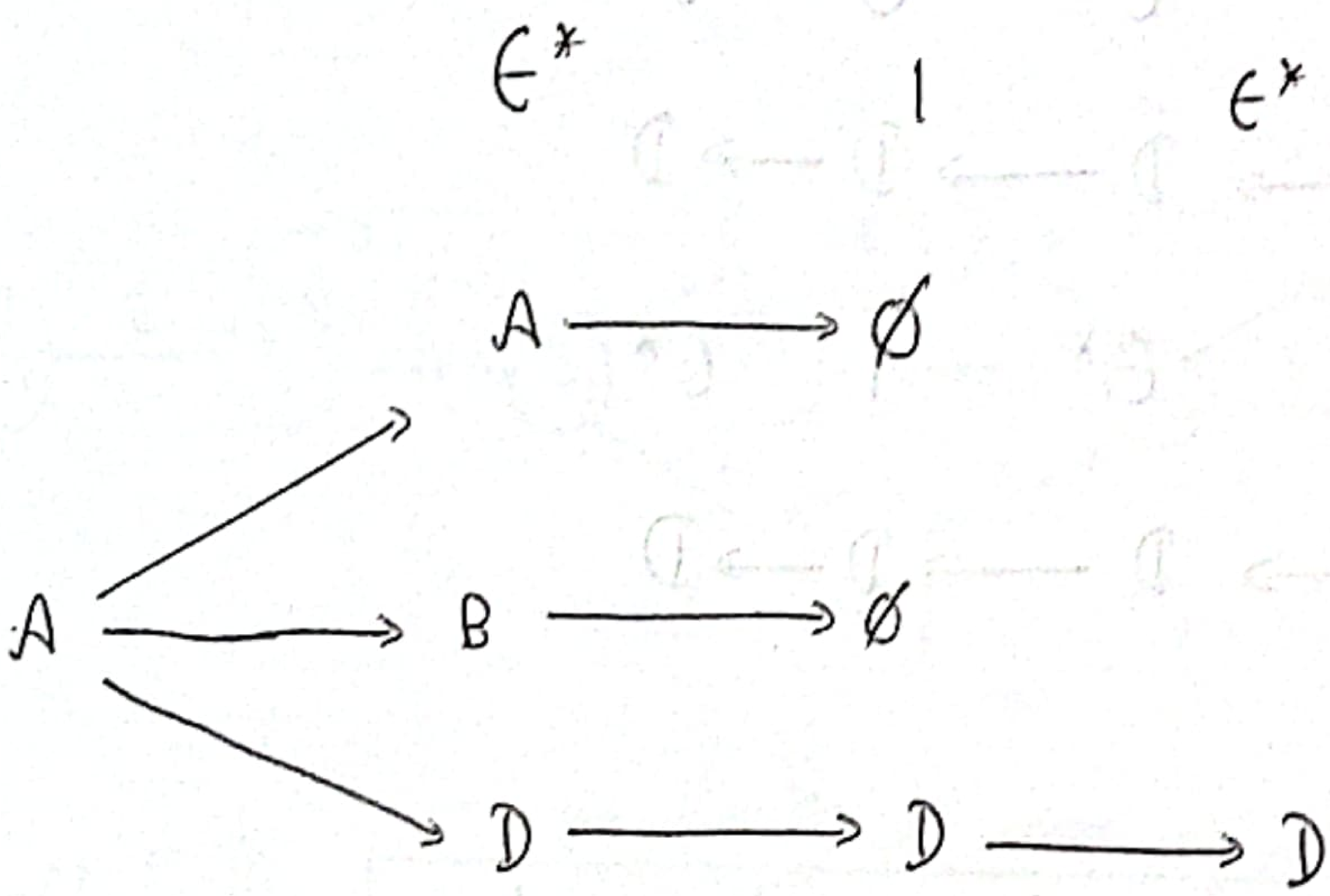


ε-Closure (A) :- what are states that you can reach by reading 'ε' from state 'A'.

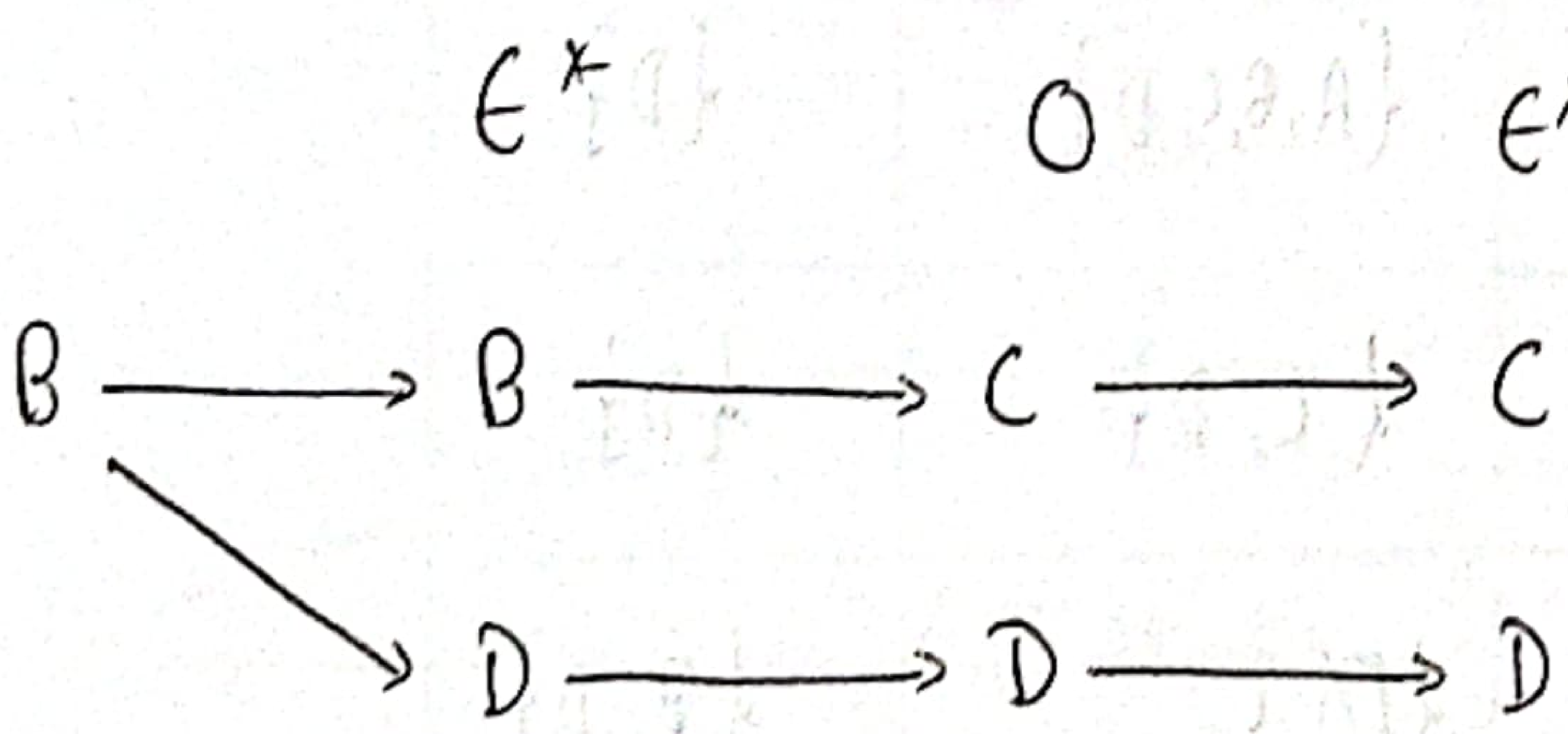
⇒ ε-Closure (A) = {A, B, D}



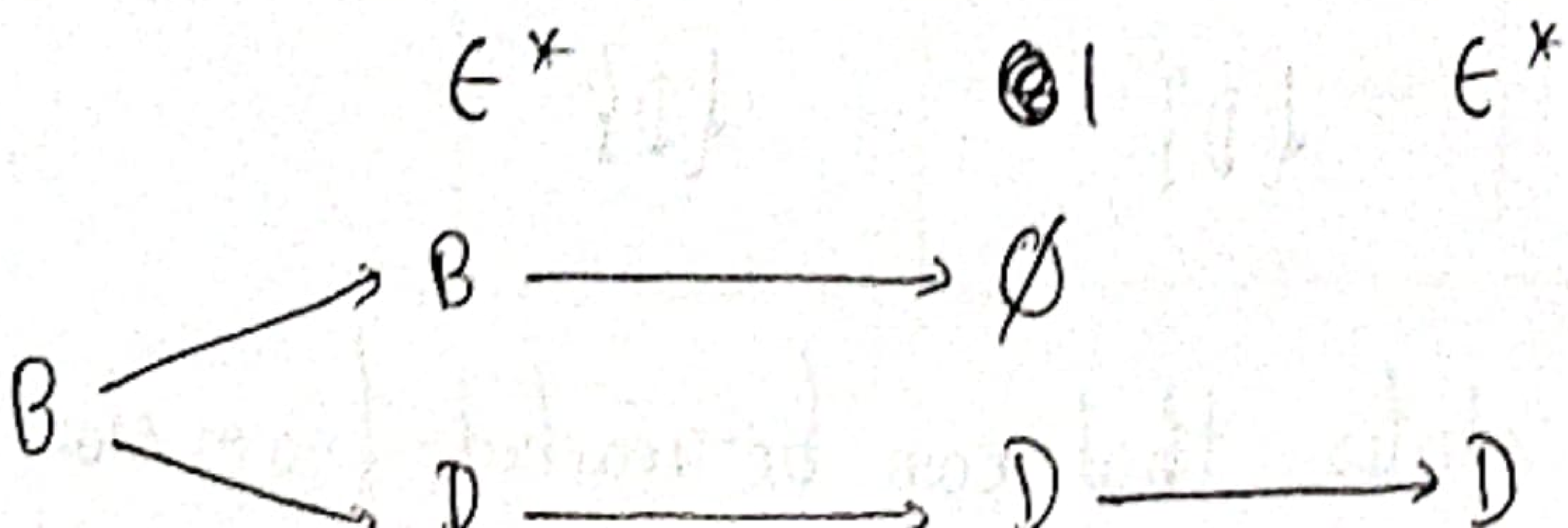
ϵ* 0 ϵ*
A A A B D
A B C D
D D C D



ϵ* 1 ϵ*
A ∅
A B ∅
D D D



ϵ* 0 ϵ*
B B C C
D D D



ϵ* 1 ϵ*
B ∅
B D D D

$$C \xrightarrow{\epsilon^*} C \xrightarrow{0} \emptyset \quad \epsilon^*$$

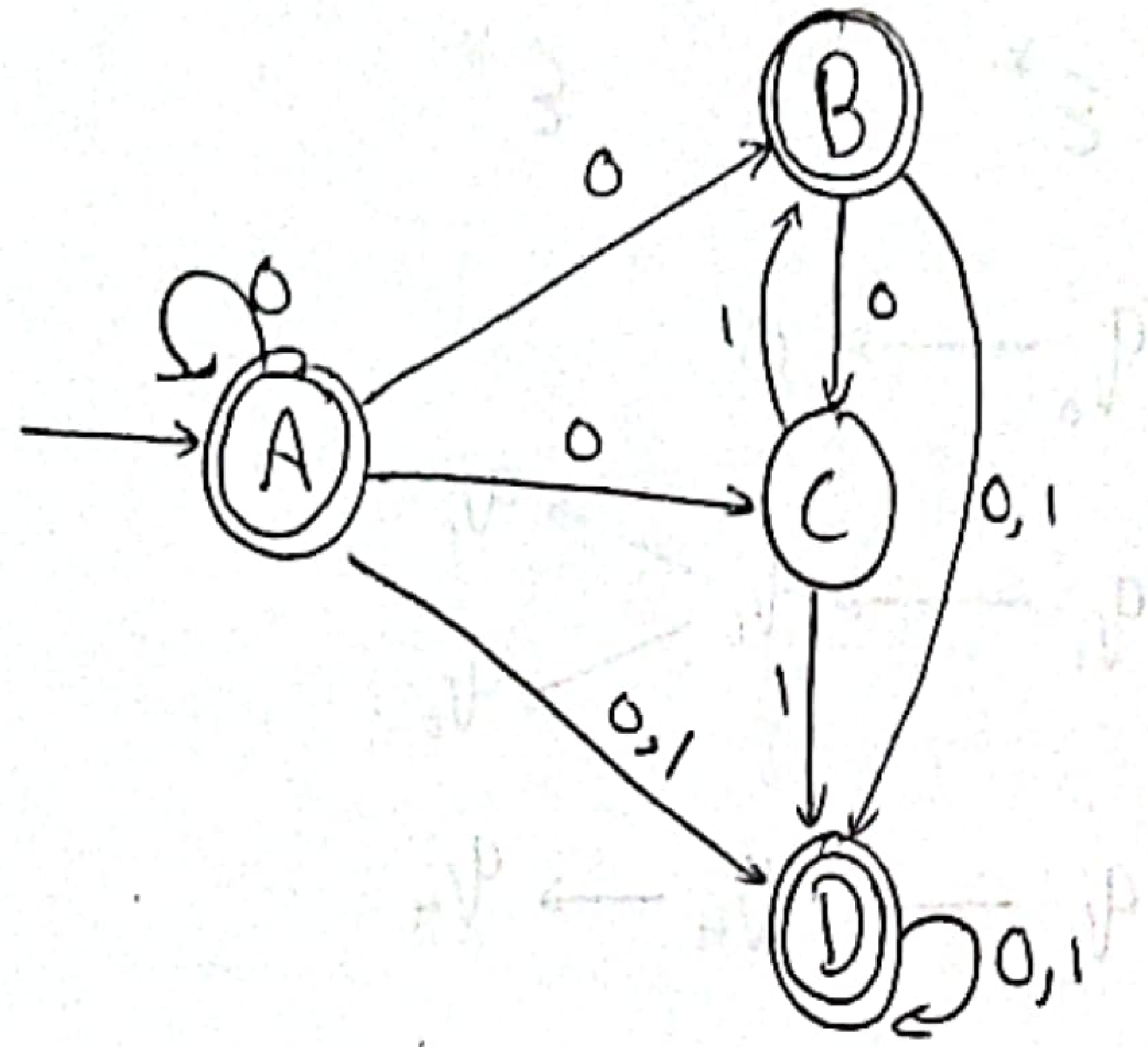
$$\begin{tikzcd} C \arrow[r, "\epsilon^*"] & C \arrow[r, "1"] & B \arrow[r, "\epsilon^*"] \arrow[dr] & B \\ & & & D \end{tikzcd}$$

$$D \xrightarrow{\epsilon^*} D \xrightarrow{0} D \xrightarrow{\epsilon^*} D$$

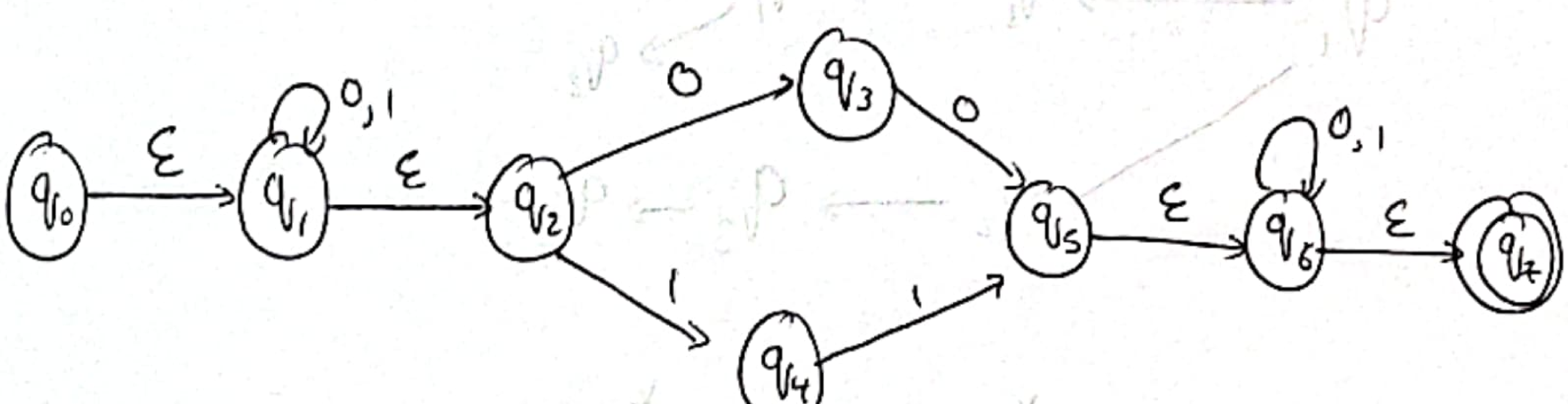
$$D \xrightarrow{\epsilon^*} D \xrightarrow{1} D \xrightarrow{\epsilon^*} D$$

	0	1
→*A	{A, B, C, D}	{D}
B	{C, D}	{D}
*C	{∅}	{B, D}
*D	{D}	{D}

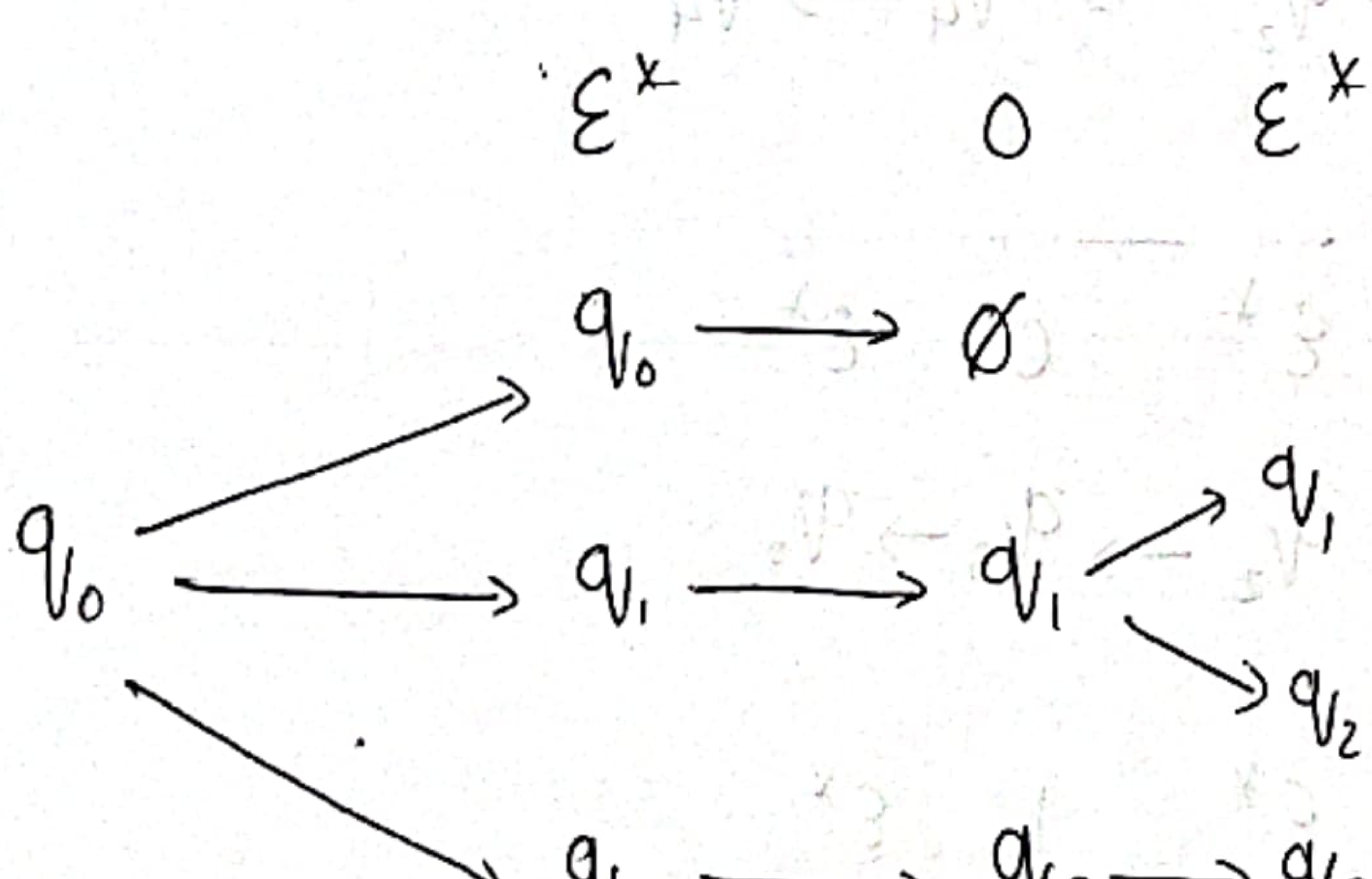
Final States :- The states that can be reached from start reading ε



② Convert ε-NFA to NFA using Subset Construction Method:-



$\varepsilon\text{-Closure}(q_0) = \{q_0, q_1, q_2\}$



ε^* 1 ε^*

$$\begin{tikzcd}
 & q_0 \arrow[r] & \emptyset & \\
 & & & q_1 \\
q_0 \arrow[uur] \arrow[r] \arrow[ddr] & q_1 \arrow[r] & q_1 \arrow[ur] \arrow[dr] & \\
 & & & q_2 \\
 & q_2 \arrow[r] & q_4 \arrow[r] & q_4
\end{tikzcd}$$

ε^* 0 ε^*

$$\begin{tikzcd}
 & & & q_1 \\
q_1 \arrow[r] \arrow[ddr] & q_1 \arrow[r] & q_1 \arrow[ur] \arrow[dr] & \\
 & & & q_2 \\
 & q_2 \arrow[r] & q_3 \arrow[r] & q_3
\end{tikzcd}$$

ε^* 1 ε^*

$$\begin{tikzcd}
 & & & q_1 \\
 & q_1 \arrow[r] & q_1 \arrow[ur] \arrow[dr] & \\
q_1 \arrow[ur] \arrow[dr] & & & q_2 \\
 & q_2 \arrow[r] & q_4 \arrow[r] & q_4
\end{tikzcd}$$

ε^* 0 ε^*

$$q_2 \rightarrow q_2 \rightarrow q_3 \rightarrow q_3$$

ε^* 1 ε^*

$$q_2 \rightarrow q_2 \rightarrow q_4 \rightarrow q_4$$

$$\begin{tikzcd} q_3 \arrow[r, "\varepsilon^*"] & q_3 \arrow[r, "0"] & q_5 \arrow[r, "\varepsilon^*"] \arrow[dr] \arrow[ddr] & q_5 \\ & & & q_6 \\ & & & q_7 \end{tikzcd}$$

$$\begin{tikzcd} q_3 \arrow[r, "\varepsilon^*"] & q_3 \arrow[r, "1"] & \emptyset \end{tikzcd}$$

$$\begin{tikzcd} q_4 \arrow[r, "\varepsilon^*"] & q_4 \arrow[r, "0"] & \emptyset \end{tikzcd}$$

$$\begin{tikzcd} q_4 \arrow[r, "\varepsilon^*"] & q_4 \arrow[r, "1"] & q_5 \arrow[r, "\varepsilon^*"] \arrow[dr] \arrow[ddr] & q_5 \\ & & & q_6 \\ & & & q_7 \end{tikzcd}$$

$$\begin{tikzcd} q_5 \arrow[r, "\varepsilon^*"] \arrow[dr] \arrow[ddr] & q_5 \arrow[r, "0"] & \emptyset & \\ & q_6 \arrow[r] & q_6 \arrow[r, "\varepsilon^*"] \arrow[dr] & q_6 \\ & q_7 \arrow[r] & \emptyset & q_7 \end{tikzcd}$$

$\varepsilon^* \quad 1 \quad \varepsilon^*$

$$\begin{tikzcd}
 & & & q_6 \\
q_5 \arrow[r] \arrow[dr] \arrow[ddr] & q_5 \arrow[r] & \emptyset & \\
 & q_6 \arrow[r] & q_6 \arrow[uur] \arrow[r] & q_7 \\
 & q_7 \arrow[r] & \emptyset &
\end{tikzcd}$$

$\varepsilon^* \quad 0 \quad \varepsilon^*$

$$\begin{tikzcd}
 & & & q_6 \\
 & q_6 \arrow[r] & q_6 \arrow[ur] \arrow[dr] & \\
q_6 \arrow[ur] \arrow[dr] & & & q_7 \\
 & q_7 \arrow[r] & \emptyset &
\end{tikzcd}$$

$\varepsilon^* \quad 1 \quad \varepsilon^*$

$$\begin{tikzcd}
 & & & q_6 \\
 & q_6 \arrow[r] & q_6 \arrow[ur] \arrow[dr] & \\
q_6 \arrow[ur] \arrow[dr] & & & q_7 \\
 & q_7 \arrow[r] & \emptyset &
\end{tikzcd}$$

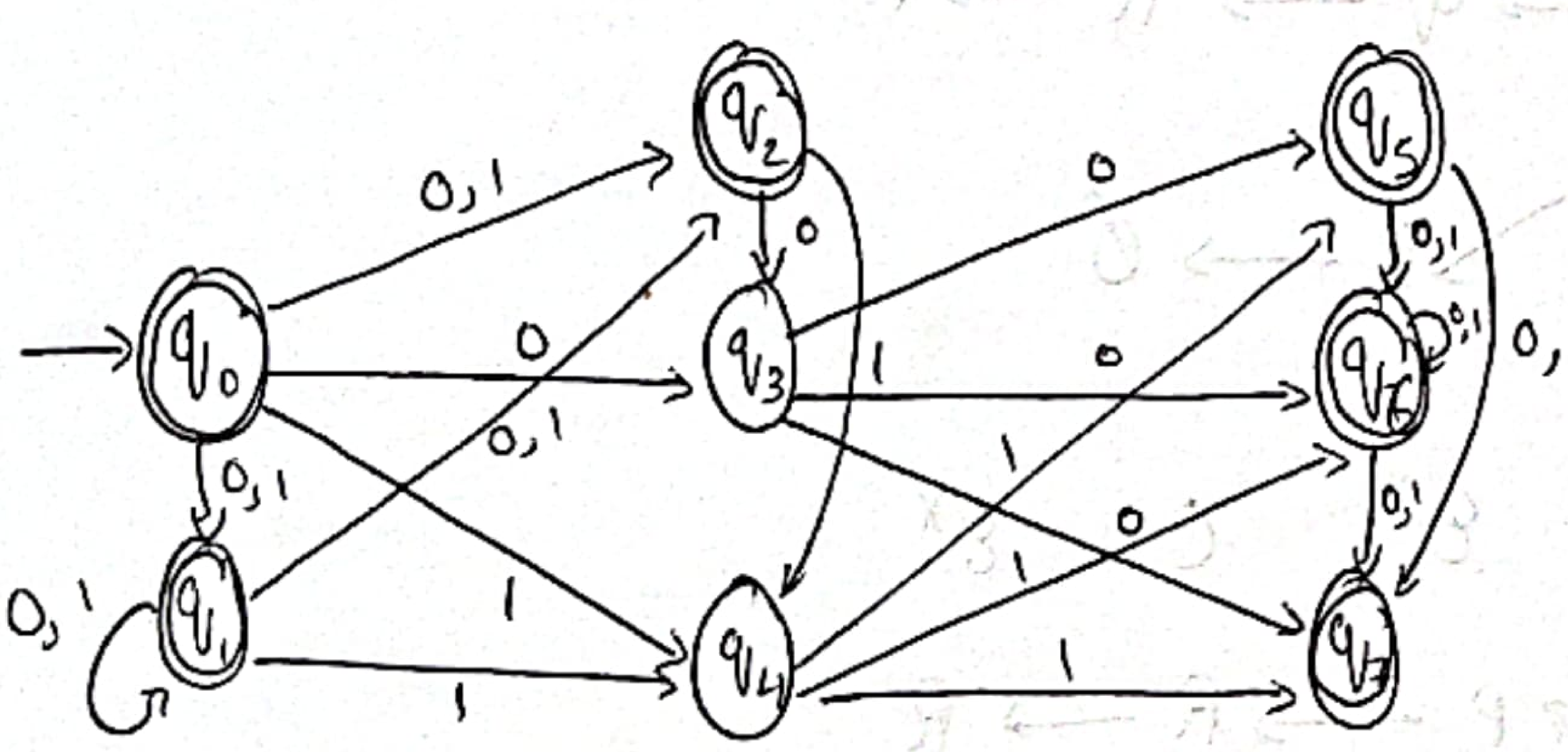
$\varepsilon^* \quad 0 \quad \varepsilon^*$

$$q_7 \longrightarrow q_7 \longrightarrow \emptyset$$

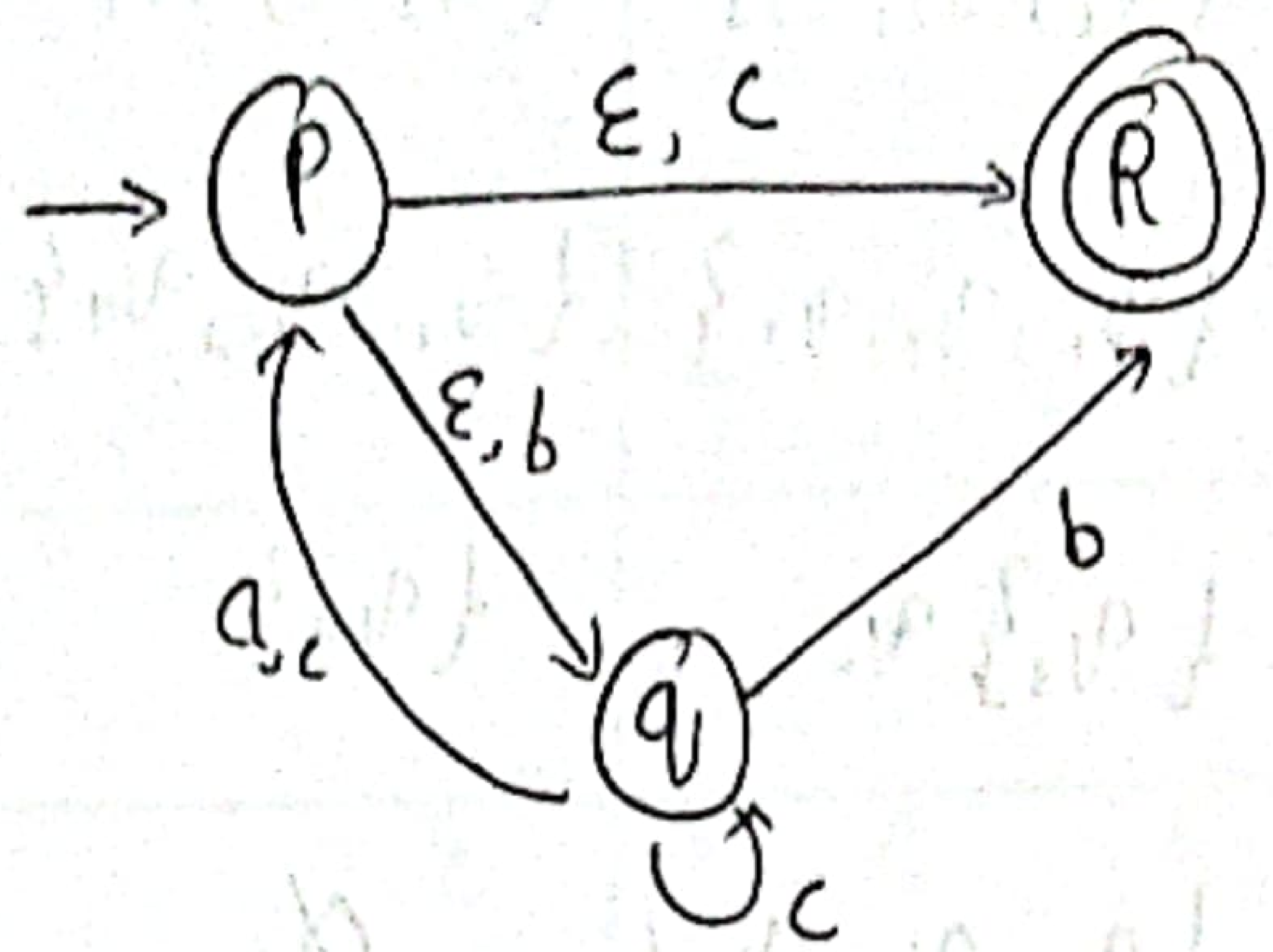
$\varepsilon^* \quad 1 \quad \varepsilon^*$

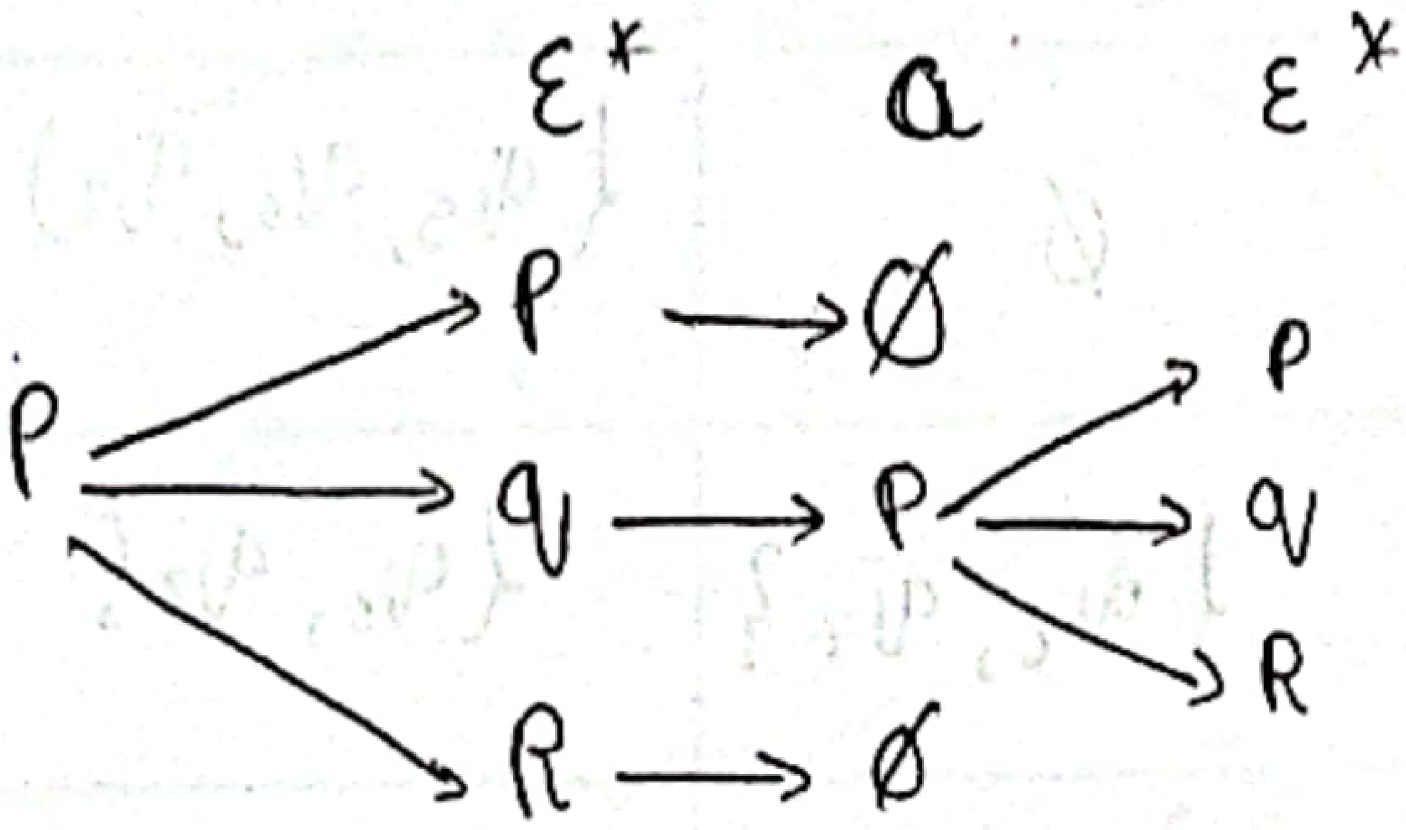
$$q_7 \longrightarrow q_7 \longrightarrow \emptyset$$

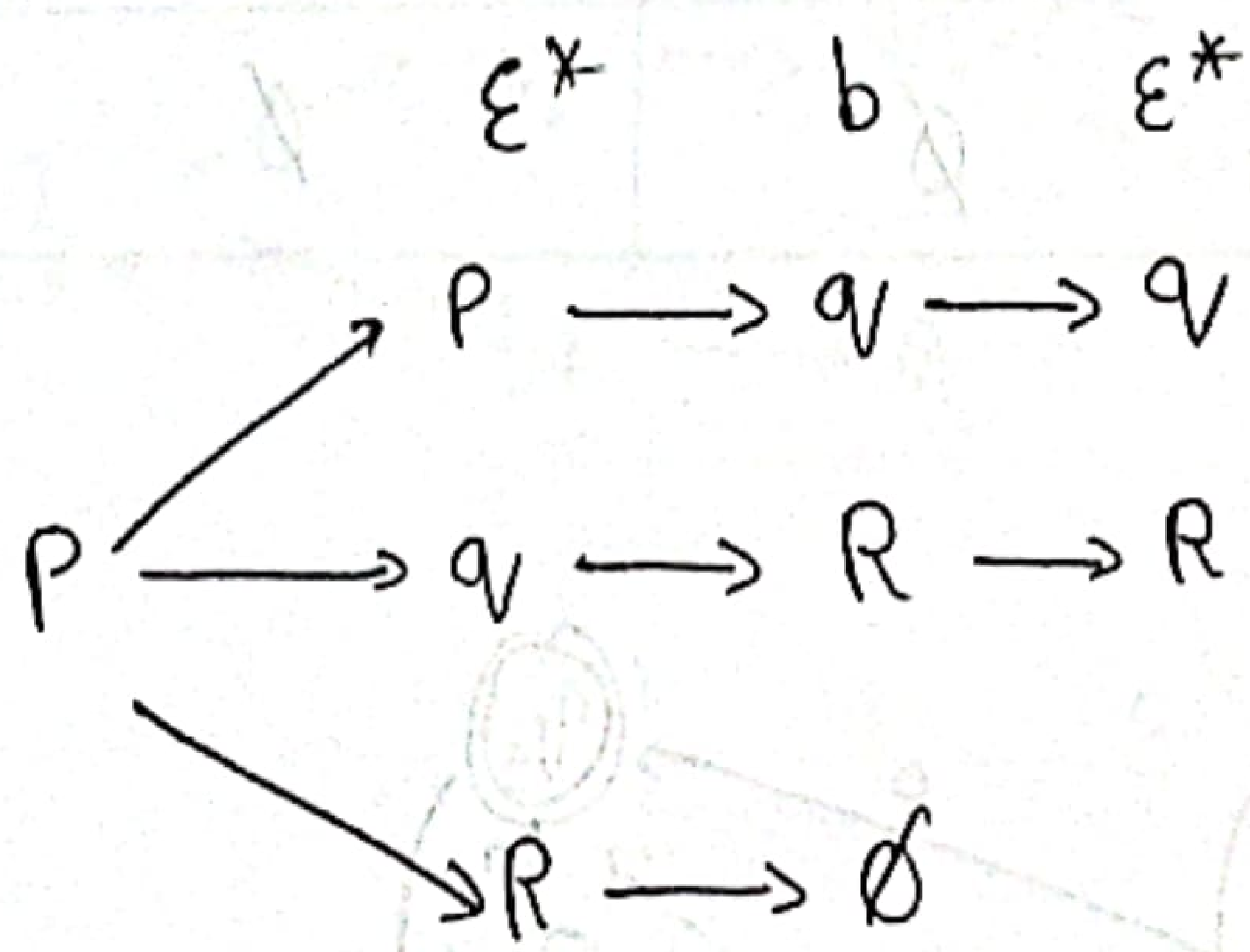
	0	1
$\rightarrow * q_0$	$\{q_1, q_2, q_3\}$	$\{q_1, q_2, q_4\}$
$* q_1$	$\{q_1, q_2, q_3\}$	$\{q_1, q_2, q_4\}$
$* q_2$	$\{q_3\}$ ~~q_2~~	$\{q_4\}$
q_3	$\{q_5, q_6, q_7\}$	$\emptyset$
q_4	$\emptyset$	$\{q_5, q_6, q_7)$
$* q_5$	$\{q_6, q_7\}$	$\{q_6, q_7\}$
$* q_6$	$\{q_6, q_7\}$	$\{q_6, q_7\}$
$* q_7$	$\emptyset$	$\emptyset$

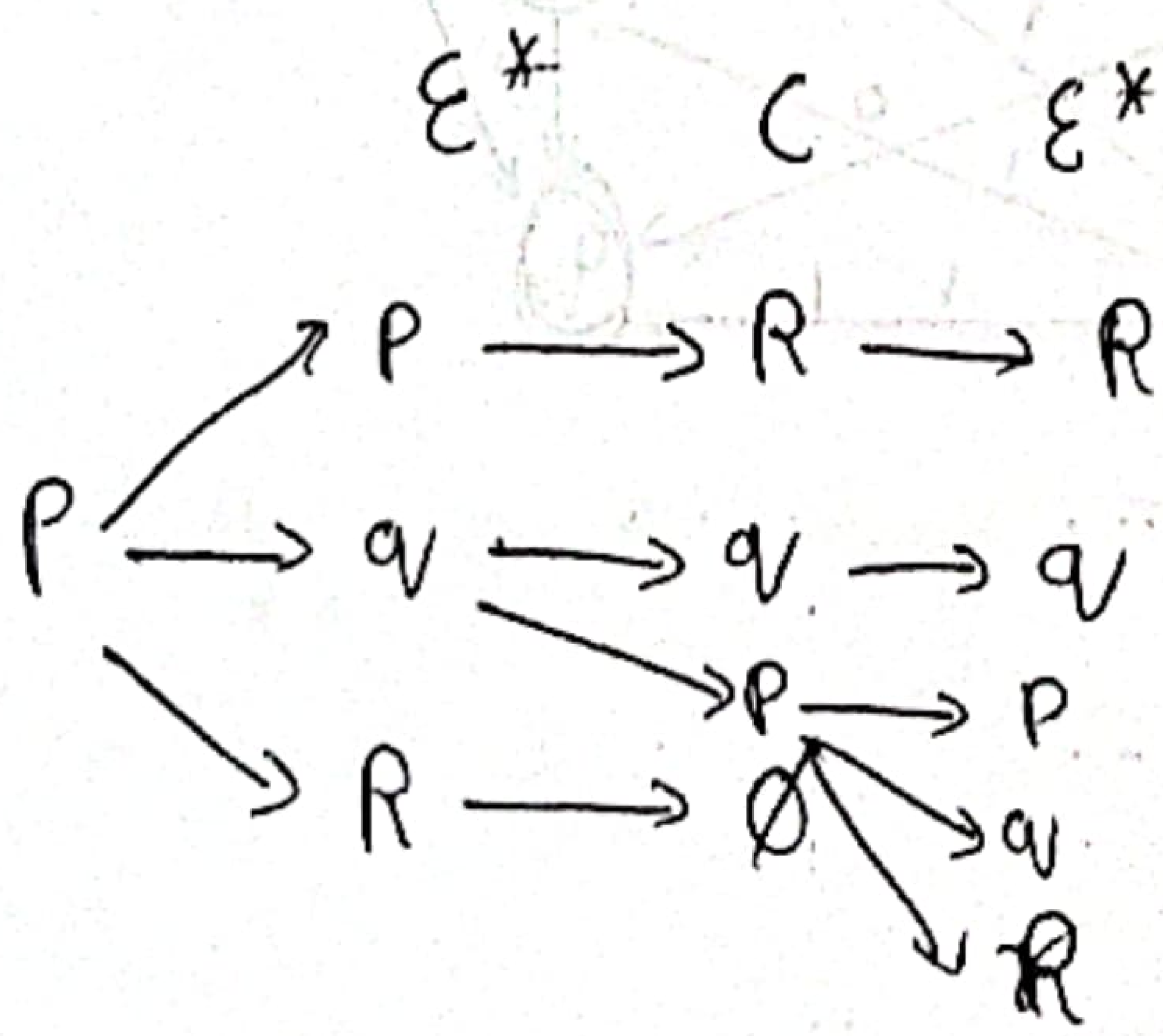


③ Convert the following into NFA :-









$\varepsilon^* \quad a \quad \varepsilon^*$

$$\begin{tikzcd}
 & & & P \\
q \arrow[r] & q \arrow[r] & P \arrow[ur] \arrow[r] \arrow[dr] & q \\
 & & & R
\end{tikzcd}$$

$\varepsilon^* \quad b \quad \varepsilon^*$

$$q \rightarrow q \rightarrow R \rightarrow R$$

$\varepsilon^* \quad c \quad \varepsilon^*$

$$\begin{tikzcd}
 & & & R \\
 & & P \arrow[ur] \arrow[r] \arrow[dr] & P \\
q \arrow[r] & q \arrow[ur] \arrow[dr] & & q \\
 & & q \arrow[r] & q
\end{tikzcd}$$

$\varepsilon^* \quad a \quad \varepsilon^*$

$$R \rightarrow R \rightarrow \emptyset$$

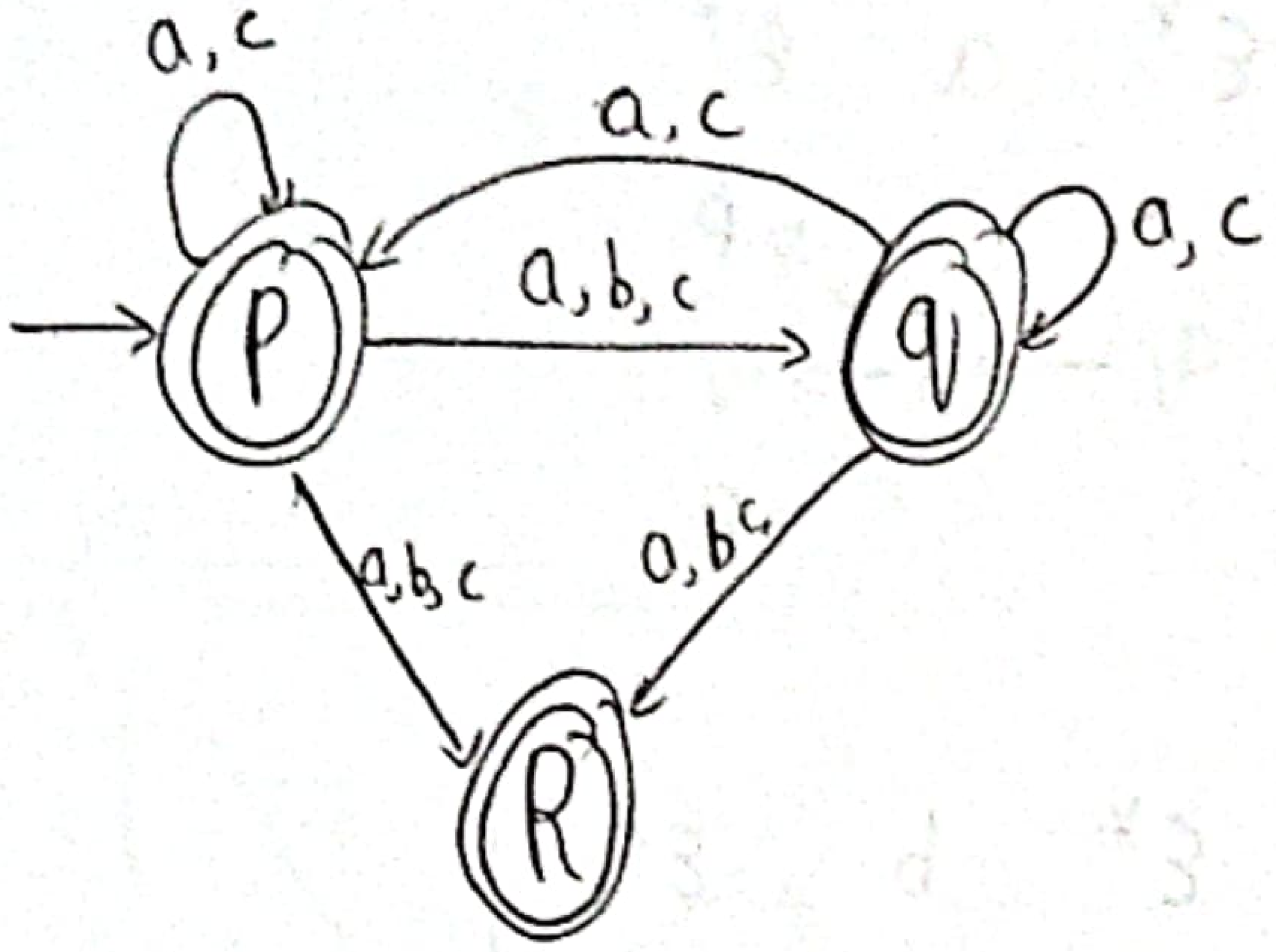
$\varepsilon^* \quad b \quad \varepsilon^*$

$$R \rightarrow R \rightarrow \emptyset$$

$\varepsilon^* \quad c \quad \varepsilon^*$

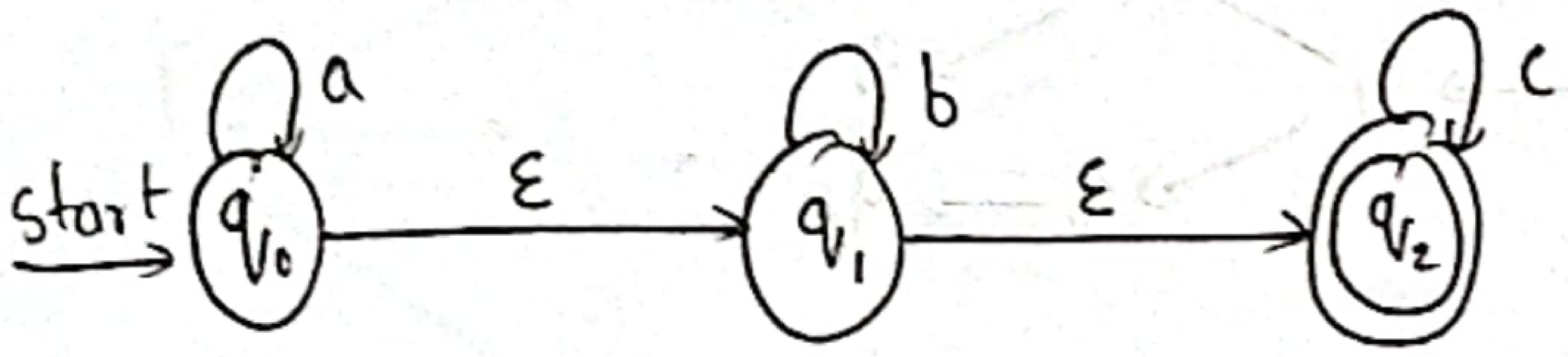
$$R \rightarrow R \rightarrow \emptyset$$

	a	b	c
$\xrightarrow{*} P$	{P, q, R}	{q, R}	{P, q, R}
*q	{P, q, R}	R	{P, q, R}
*R	$\emptyset$	$\emptyset$	$\emptyset$



⇒ Conversion from ε-NFA to DFA :-

① Convert the state diagram from ε-NFA to DFA :-



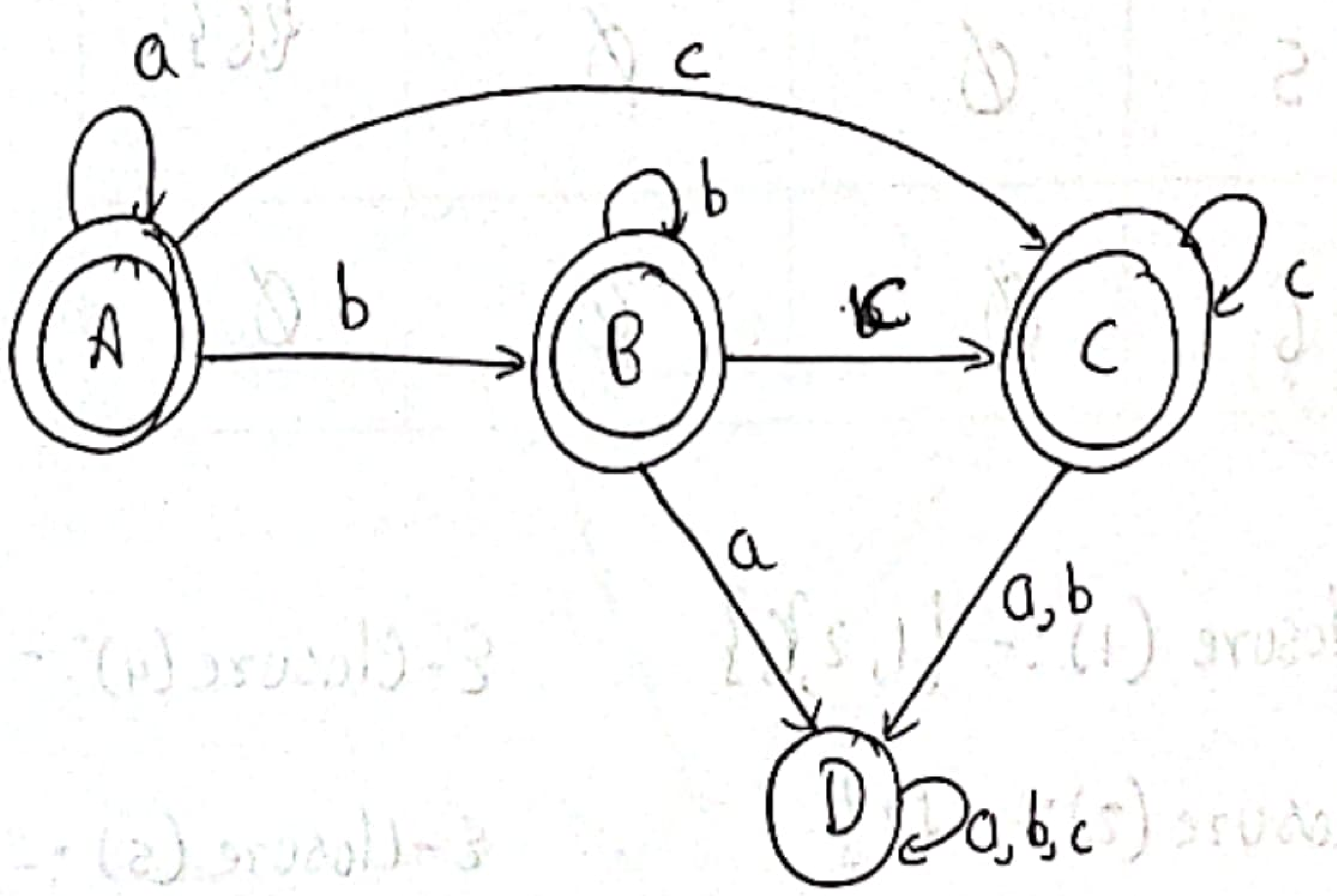
δ_ε	a	b	c	ε
→ q_0	$\{q_0\}$	∅	∅	$\{q_1\}$
q_1	∅	$\{q_1\}$	∅	q_2
* q_2	∅	∅	$\{q_2\}$	∅

ε-closure (q_0) :- $\{q_0, q_1, q_2\}$

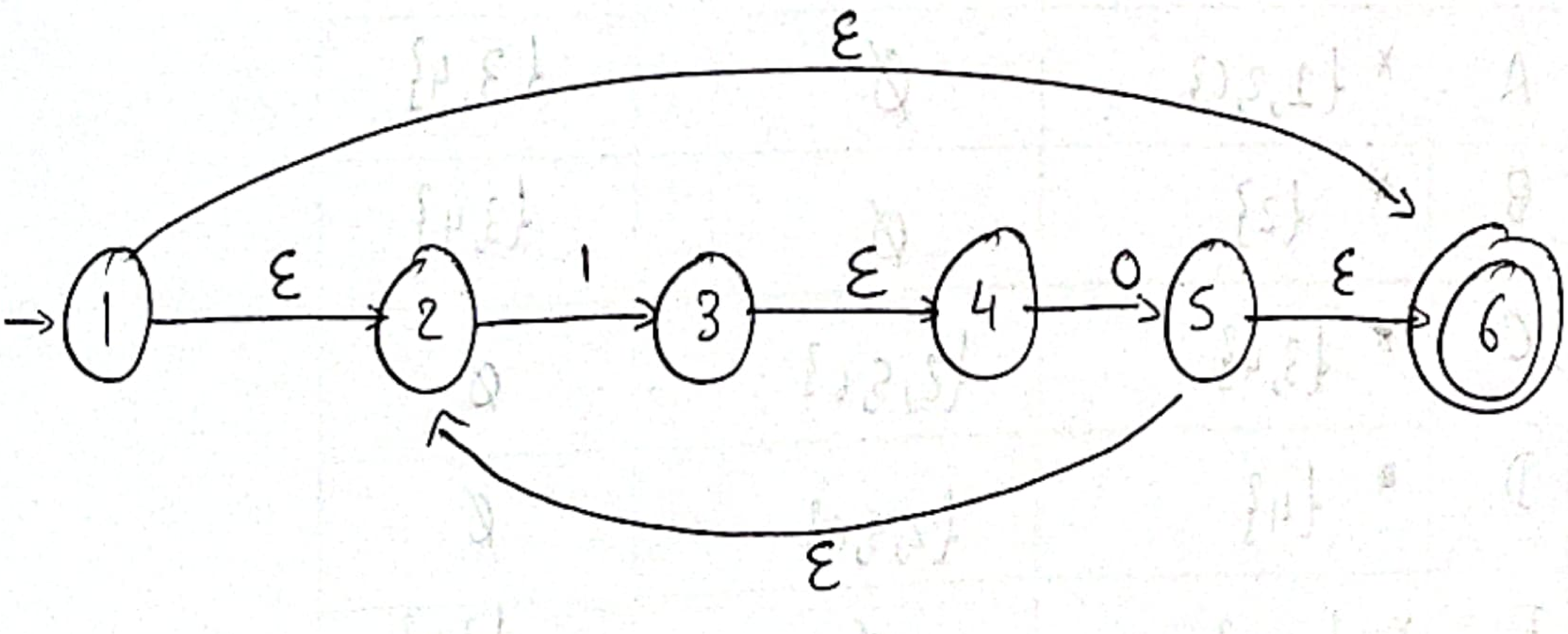
ε-closure (q_1) :- $\{q_1, q_2\}$

ε-closure (q_2) :- $\{q_2\}$

	δ_D	a	b	c
A ⇐	$*\{q_0, q_1, q_2\}$	$\{q_0, q_1, q_2\}$	$\{q_1, q_2\}$	$\{q_2\}$
B ⇐	$*\{q_1, q_2\}$	$\emptyset$	$\{q_1, q_2\}$	$\{q_2\}$
C ⇐	$*\{q_2\}$	$\emptyset$	$\emptyset$	$\{q_2\}$



② Convert ε-NFA to equivalent DFA :-



δ_ε	0	1	ε
1	$\emptyset$	$\emptyset$	$\{2,6\}$
2	$\emptyset$	3	$\emptyset$
3	$\emptyset$	$\emptyset$	$\{4\}$
4	5	$\emptyset$	$\emptyset$
5	$\emptyset$	$\emptyset$	$\{6\}$
6	$\emptyset$	$\emptyset$	$\emptyset$

ε-Closure (1) :- $\{1,2,6\}$

ε-Closure (2) :- $\{2\}$

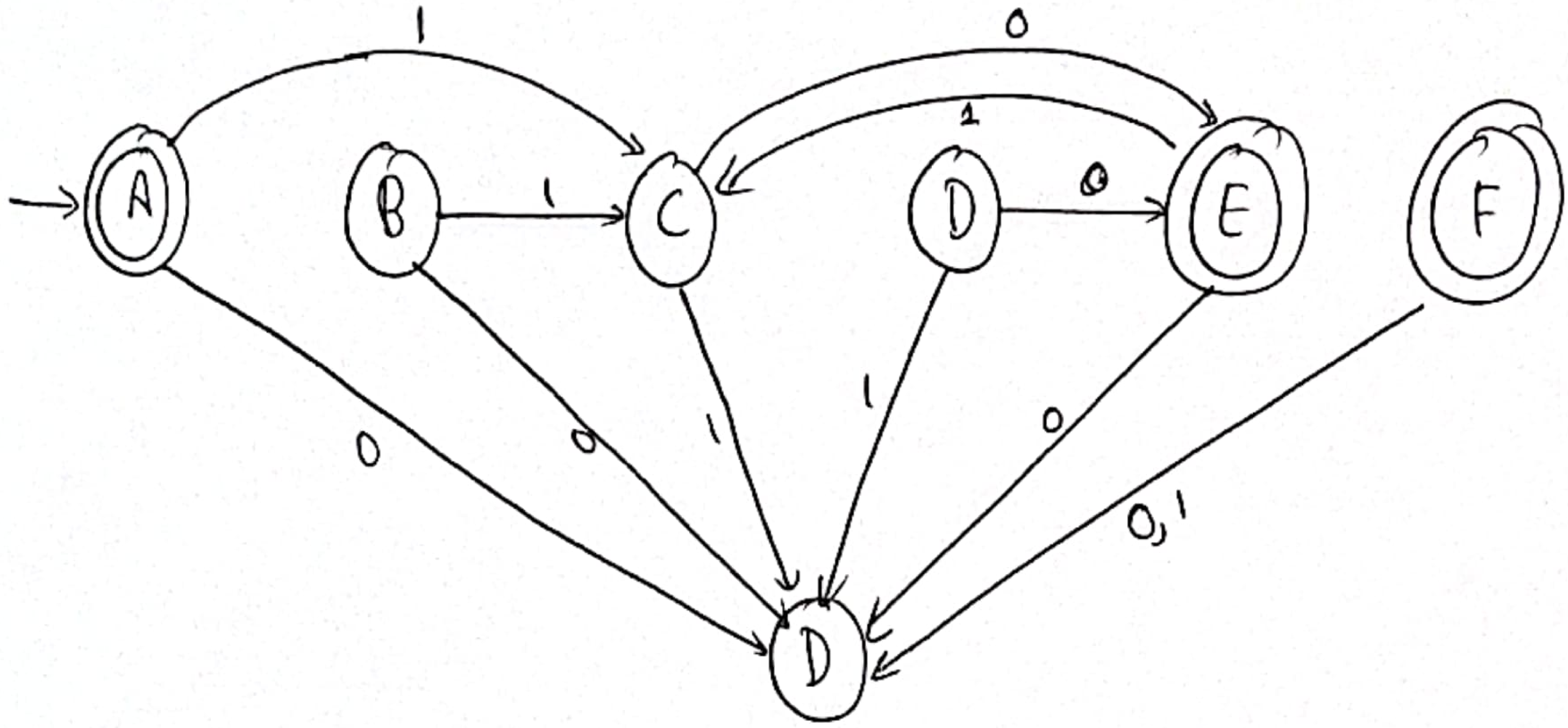
ε-Closure (3) :- $\{3,4\}$

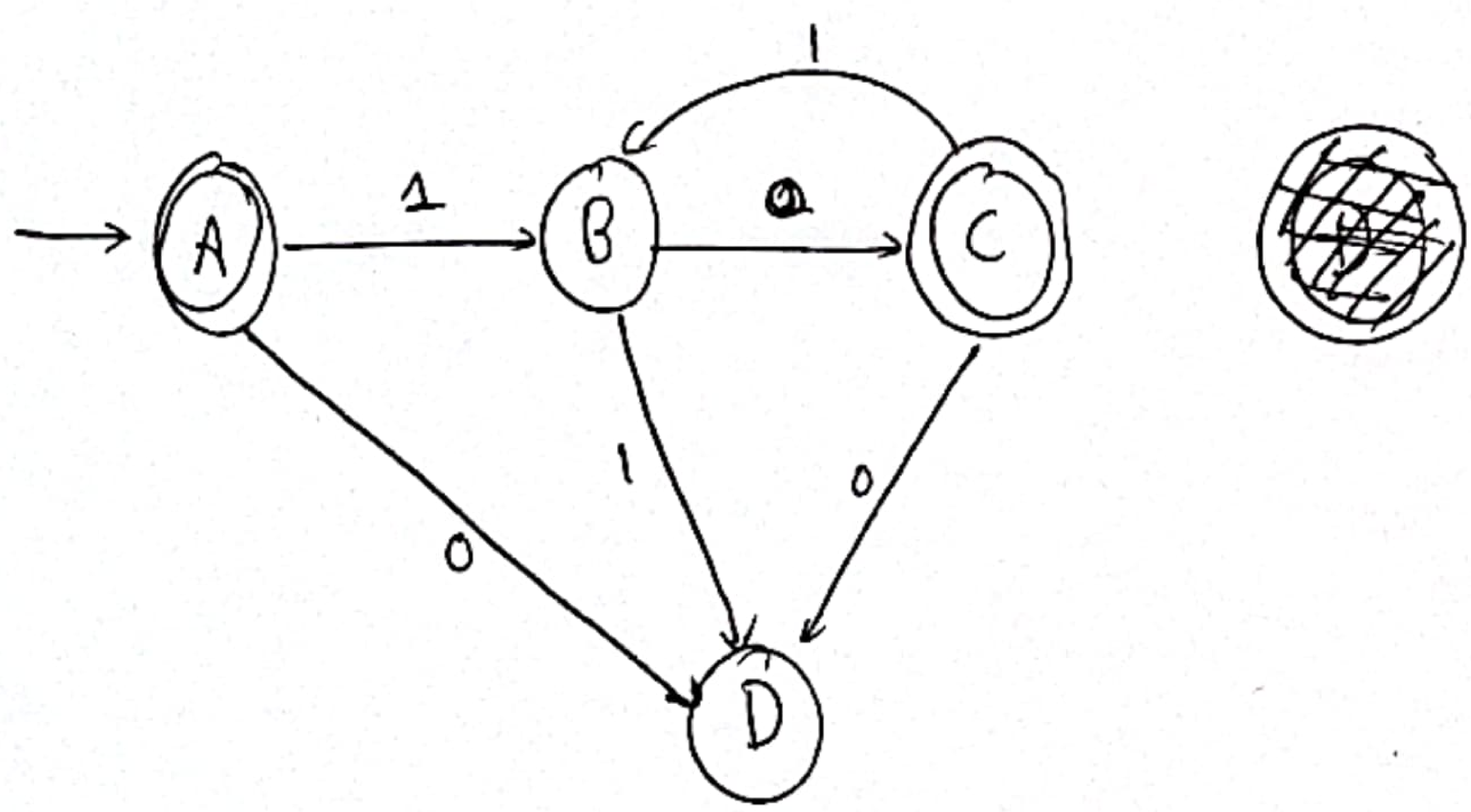
ε-Closure (4) :- $\{4\}$

ε-Closure (5) :- $\{2,5,6\}$

ε-Closure (6) :- $\{6\}$

		δ_D	0	1
A	A	* $\{1,2,6\}$	$\emptyset$	$\{3,4\}$
A	B	* $\{2\}$	$\emptyset$	$\{3,4\}$
B	C	* $\{3,4\}$	$\{2,5,6\}$	$\emptyset$
B	D	* $\{4\}$	$\{2,5,6\}$	$\emptyset$
C ←	E	* $\{2,5,6\}$	$\emptyset$	$\{3,4\}$
D ←	F	* $\{6\}$	$\emptyset$	$\emptyset$


A
B
C
D
E
F
D
1
1
0
1
0
0
0
1
1
0
0,1


A
B
C
D
1
1
0
0
1
0

→ Minimization of DFA by Table Filling Method :-

(Myhill nerode Method)

(i) Draw a Table for all pairs of states (P, q)

Columns :- A to F if (A to G states are present)

Rows :- B to G if (A to G states are present)

	A	B	C	D	E	F
B						
C						
D						
E						
F						
G						

(ii) Mark all the pairs where $P \in F$ & $q \notin F$

$P \notin F$ & $q \in F$

(~~In~~distinguishable set)

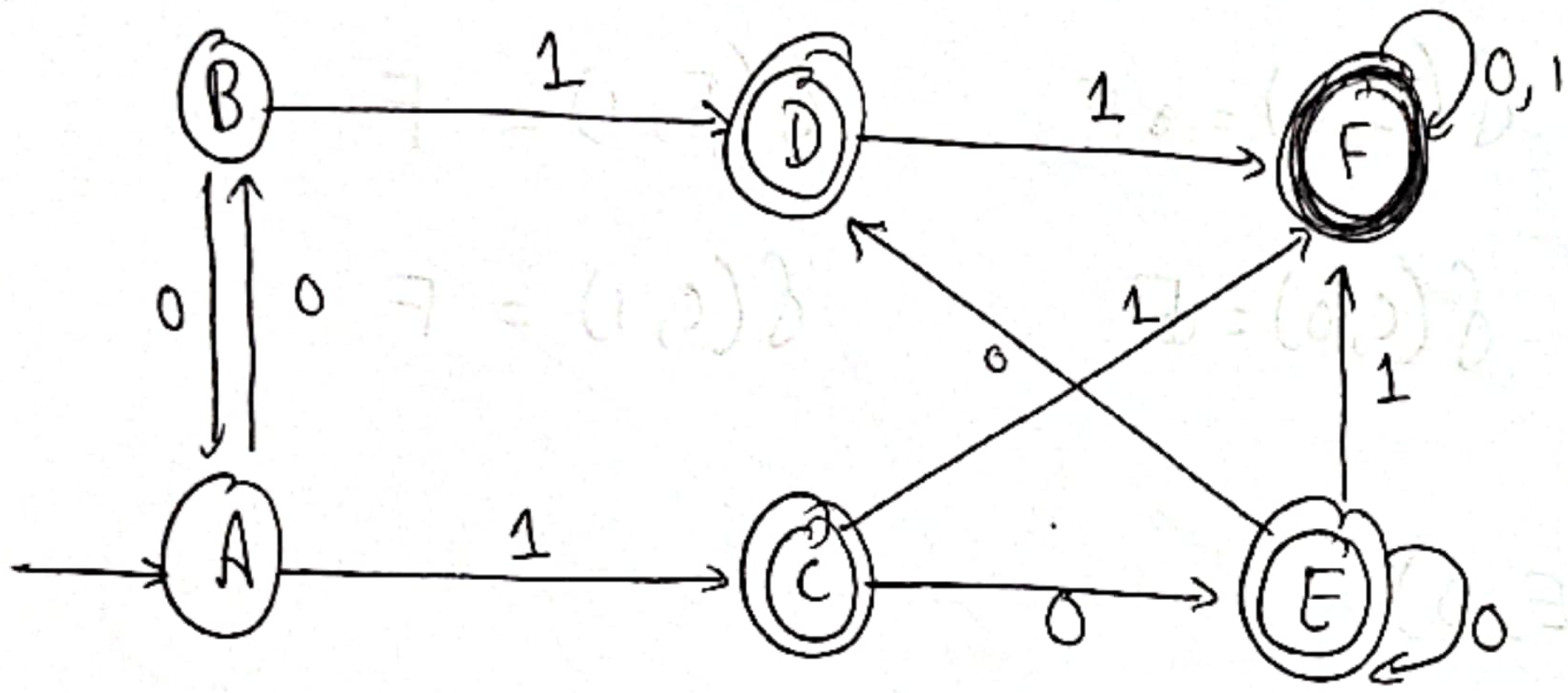
<u>Note</u> :- $P \in F$ & $q \in F$

$\underline{P \notin F}$ & $q \notin F$ } InDistinguishable.

(iii) If any unmarked pairs (P, q) such that $\delta(P, x)$, $\delta(q, x)$ is marked, then marks (P, q)

(iv) Combine all the unmarked pairs and make them as a single state

(1) Minimize the states of DFA by Table filling method.



	A	B	C	D	E
B	X				
C	✓	✓			
D	✓	✓	X		
E	✓	✓	X	X	
F	✓	✓	✓	✓	✓

(B, A)

$\delta(B,0) = A$ $\delta(B,1) = C$

$\delta(A,0) = B$ $\delta(A,1) = D$

(D, C)

$\delta(D,0) = E$ $\delta(D,1) = F$

$\delta(C,0) = E$ $\delta(C,1) = F$

(E, C)

$\delta(E,0) = F$ $\delta(E,1) = F$

$\delta(C,0) = E$ $\delta(C,1) = F$

(E, D)

$\delta(E,0) = E$ $\delta(E,1) = F$

$\delta(D,0) = E$ $\delta(D,1) = F$

(F, A)

$\delta(F,0) = F$ $\delta(F,1) = F$

$\delta(A,0) = B$ $\delta(A,1) = C$

(F, B)

$\delta(F, 0) = F$ $\delta(F, 1) = F$

$\delta(B, 0) = A$ $\delta(B, 1) = D$

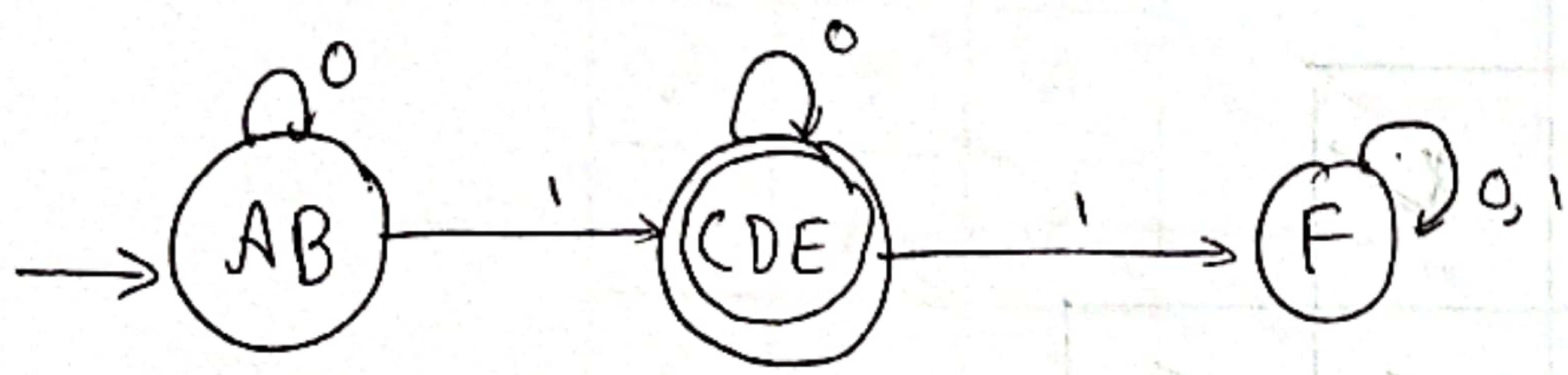
~~(F, E)~~

~~$\delta(F, 0) = F$~~ ~~$\delta(F, 1) = F$~~

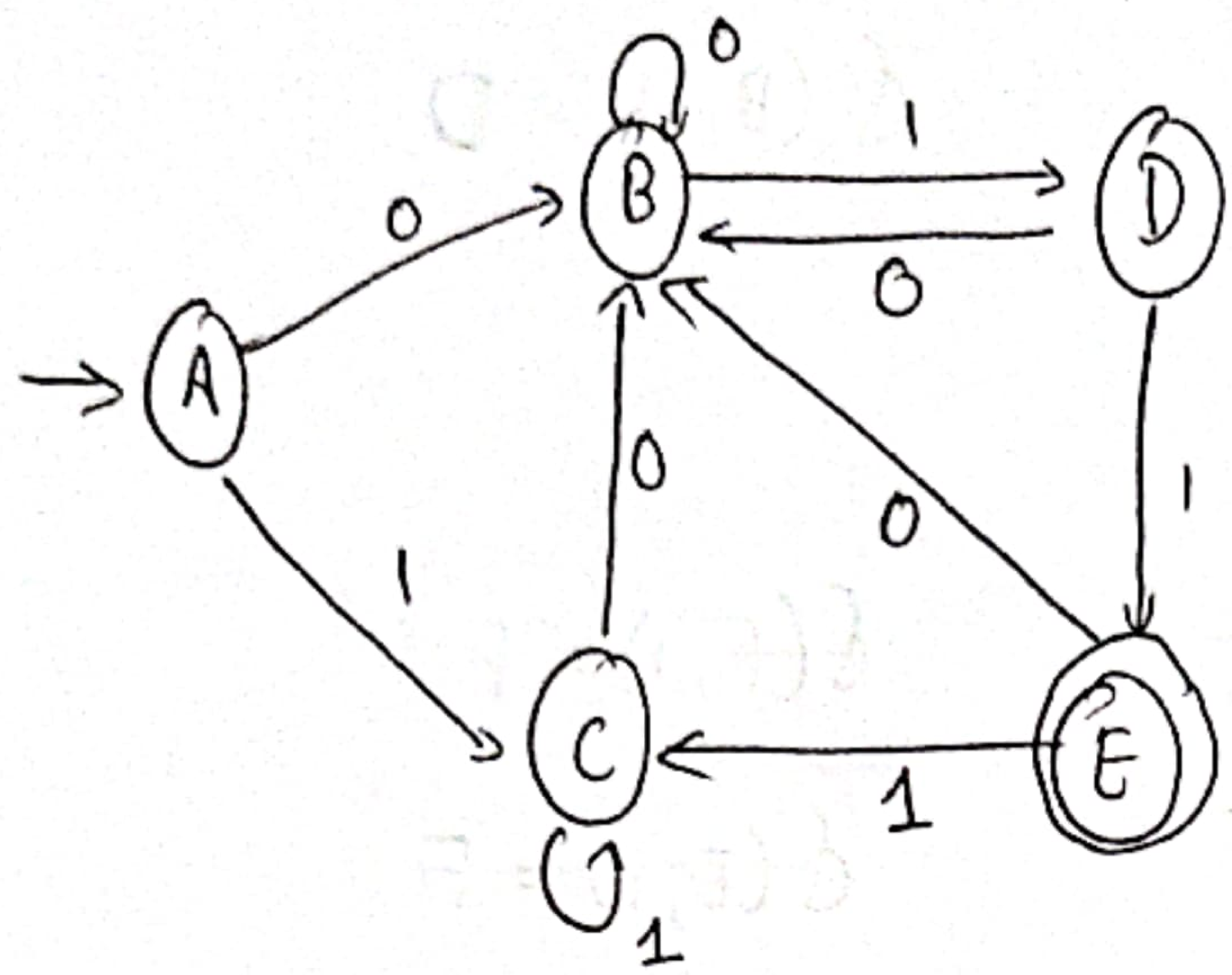
~~$\delta(E, 0) = E$~~ ~~$\delta(E, 1) = F$~~

Pairs (Unmarked) :-

(A, B) (C, D) (E, C) (E, D) ~~(F, C)~~ ~~(F, D)~~ ~~(F, E)~~



② Reduce the following DFA :-

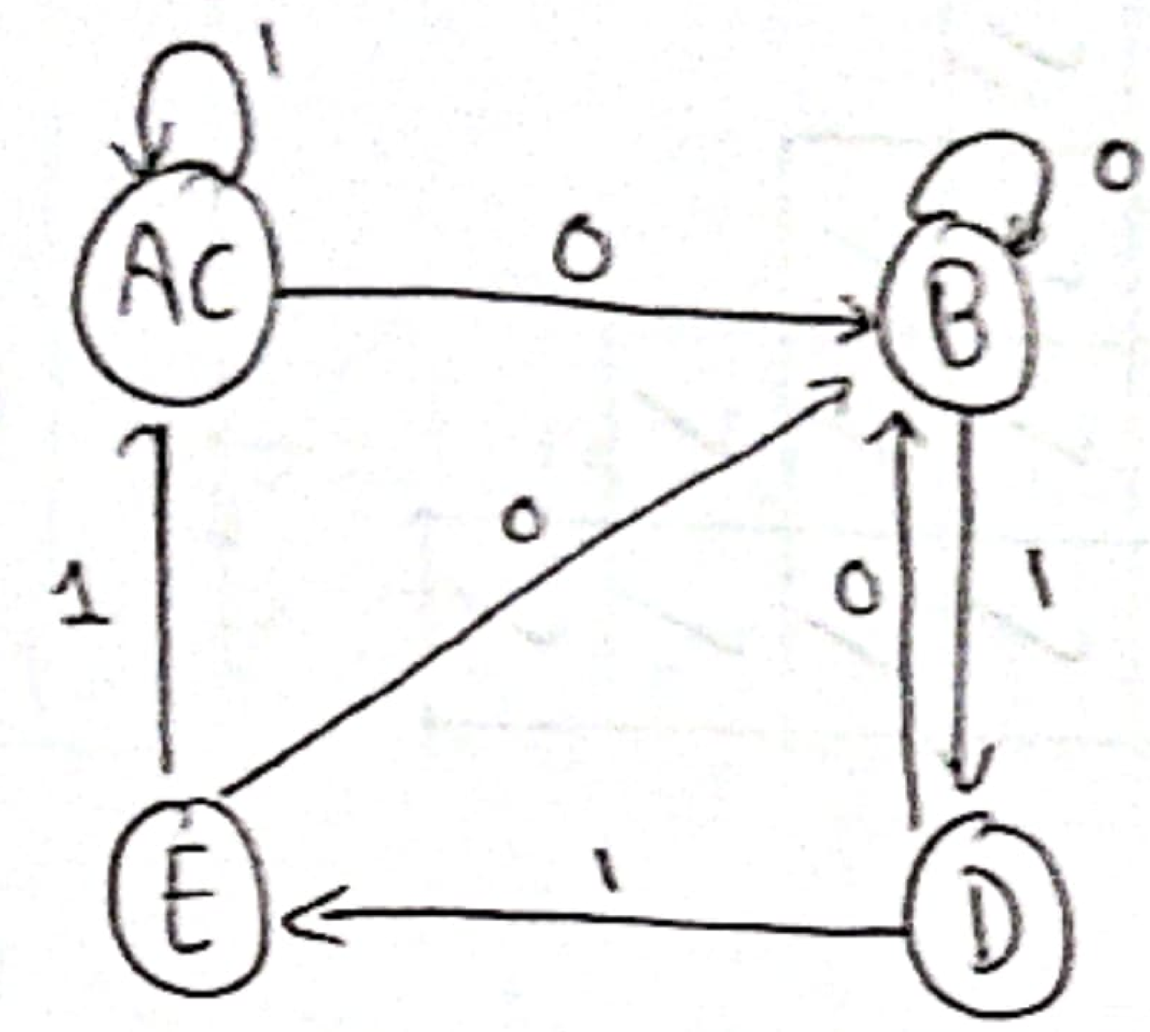


	A	B	C	D
B	✓			
C	X	✓		
D	✓	✓	✓	
E	✓	✓	✓	✓

δ	0	1
A	B	C
B	B	D
C	B	C
D	B	E
E	B	C

Unmarked Pairs :- (A, C)

Minimized DFA :-



(3) ⇒ Minimize the states of DFA by Table Filling Method :-

δ	0	1
A	B	A
B	A	C
C	D	B
D*	D	A
E	D	F
F	G	E
G	F	G

	A	B	C	D	F	E
B	✓					
C	✓✓	✓✓				
D	✓✓	✓✓	✓✓			
E	✓✓	✓✓	✗	✓		
F	✓	✗	✓	✓	✓	
G	✗	✓	✓	✓	✓	✓

Unmarked :- (B, F) (E, C) (G, A)