POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

TOC (Theory of Computation)

Books:-
1. K.L.P Mishra
2. Adesh Kumar Pandey
3. D.P Sharma.

Theory of Automata
↓
Machine.

History:-

1930's ⟶ Compiler
1940 & 1950 ⟶ fine to Automata
1950 ⟶ Chomsky grammar
1969 ⟶ Turing Machine's

Importance:-

Events — Inputs

States.

Useful. States

Not useful State.

Main Ideas, Questions & Summary:

Library / Website Ref.:-

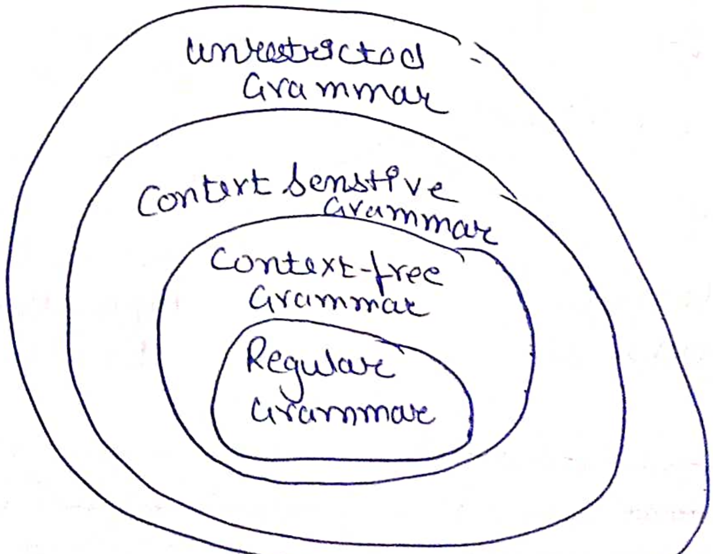
(1) Language
(2) Grammar
(3) $\boxed{\text{Automata}}$ → latin word.

→ Machine → Automatically.

↓ Automatic.

Naum Chomsky classification

S.No	class	Grammar	Automata (Model/Language)	Language
1.	Type-3	Regular Grammar	finite Automata (I)	Regular Language
2.	Type-3.	Context free Grammar.	Push Down Automata (II)	Context free language
3.	Type-1	Context sensitive Grammar	linear bounded. Automata (III)	Context sensitive Language
4.	Type-0.	unrestricted Grammar	Turing Machine (IV)	Recursive. Enumerated language.



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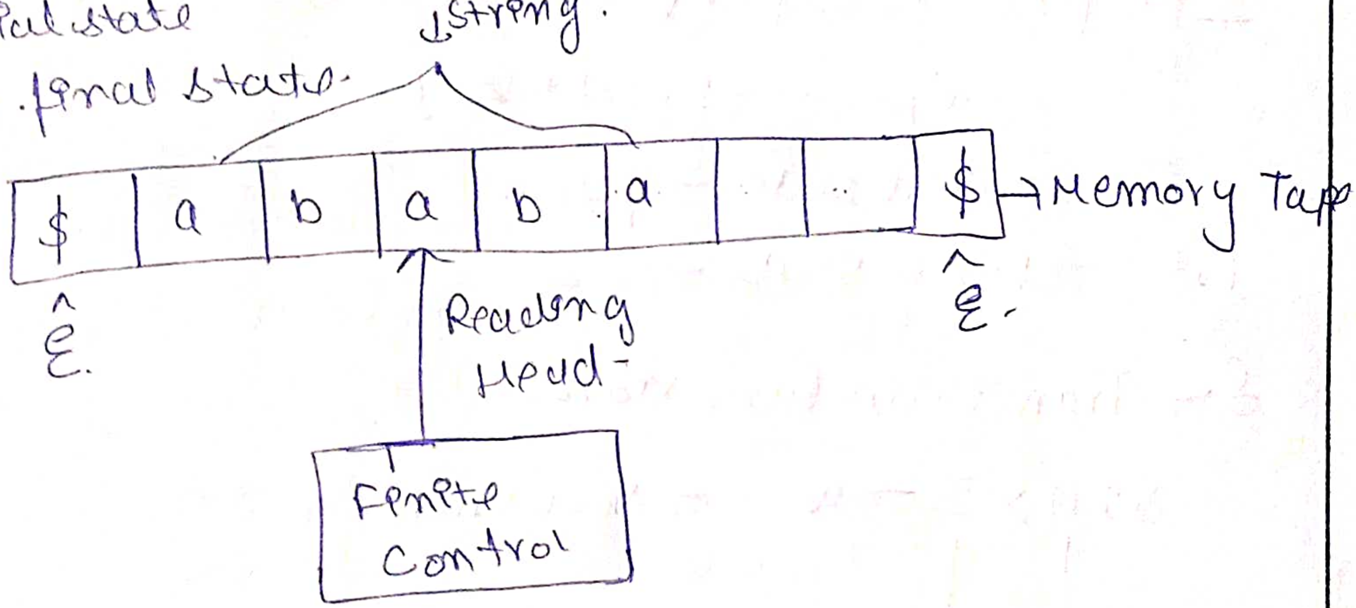
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Finite Automata

→ finite & fixed Memory
→ strings
→ Acceptable are reachable
→ initial state
→ End final state.



→ Representation of finite Automata.
① Transition Graph
② Transition Tape.

Representation of FA

Transition Graph | Transition System

Transition Table

Main Ideas, Questions & Summary:

Library / Website Ref.:-

⇒ Tuples (special symbols

$M = (Q, \Sigma, \delta, I.S, F.S)$

↓

Machine

Q → finite set of states.

$\{q_0, q_1, q_2 \text{ ------- }\}$.

Σ → finite set of input alphabets.

$\{0 \text{ ---- } 9,\ a \text{ to } z\}$

I.S → Initial state → q_0

F.S → final State → q_2

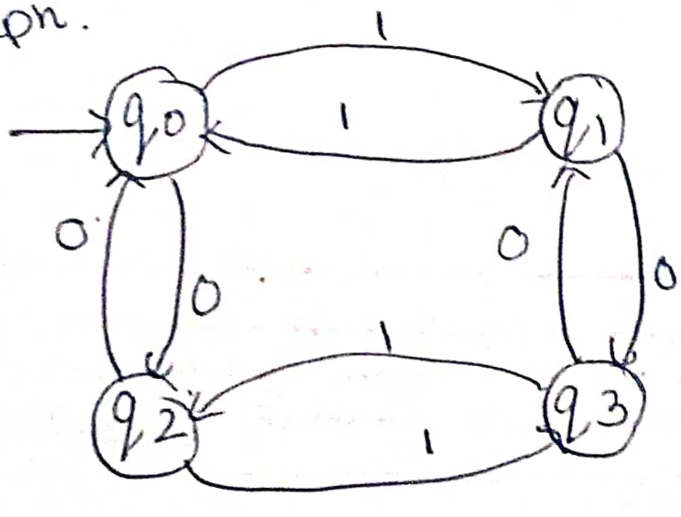
δ → Transition function.

$\delta : Q \times \Sigma \rightarrow Q \longrightarrow$ Next state.

Q ↓ Present state (P.S)

Σ — input i/p

Q. Construct the Transition Tabel for the Transition Graph.



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Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Transition Table

State	Input 0	Input 1
$\rightarrow q_0$	q_2	q_1
q_1	q_3	q_0
q_2	q_0	q_3
q_3	q_1	q_2

$M = (Q, \Sigma, \delta, I.S, F.S)$

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

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

$I.S = q_0$

$F.S = q_3$.

$(\{q_0, q_1, q_2, q_3\}, \{0,1\}, q_0, q_3)$

$\delta : Q \times \Sigma \longrightarrow Q$

$q_0 \cdot 0 \rightarrow q_2$

$q_0 \cdot 1 \rightarrow q_1$

$q_1 \cdot 0 \rightarrow q_3$

$q_1 \cdot 1 \rightarrow q_0$

$q_2 \cdot 0 \rightarrow q_0$

$q_2 \cdot 1 \rightarrow q_3$

$q_3 \cdot 0 \rightarrow q_1$

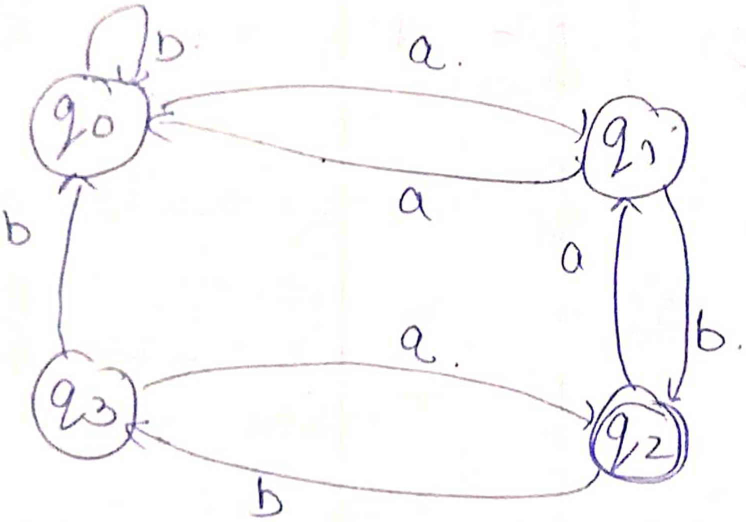
$q_3 \cdot 1 \rightarrow q_2$

Main Ideas, Questions & Summary:-

Library / Website Ref.:-

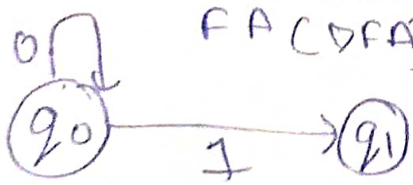
Q. Consider the state Transition Table and draw its Transition Diagram

State	i/p a	i/p b
→ q0	q1	q0
q1	q0	q2
q2	q1	q3
q3	q2	q0



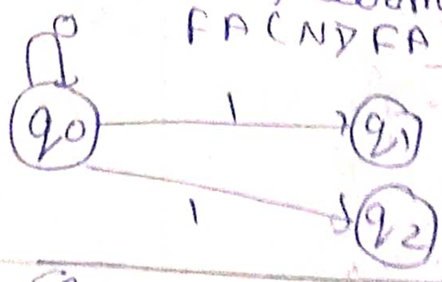
Types of Finite Automata

Deterministic FA (DFA)



$$\boxed{\delta : Q \times \Sigma \rightarrow Q}$$

Non-Deterministic FA (NDFA)



$$\boxed{\delta : Q \times \Sigma \rightarrow 2^Q}$$

String Acceptability | Reachability.

↳ string End
↳ M/C → final state

∴ String is acceptable only when string Ends and we Reach to our final state.

Steps

① State Transition Table $\xrightarrow{\text{Convert}}$ State Transition Diagram.

State Transition Diagram $\xrightarrow{\text{Convert}}$ State Transition Tabels.

② Tuples.

③ String Acceptability test.

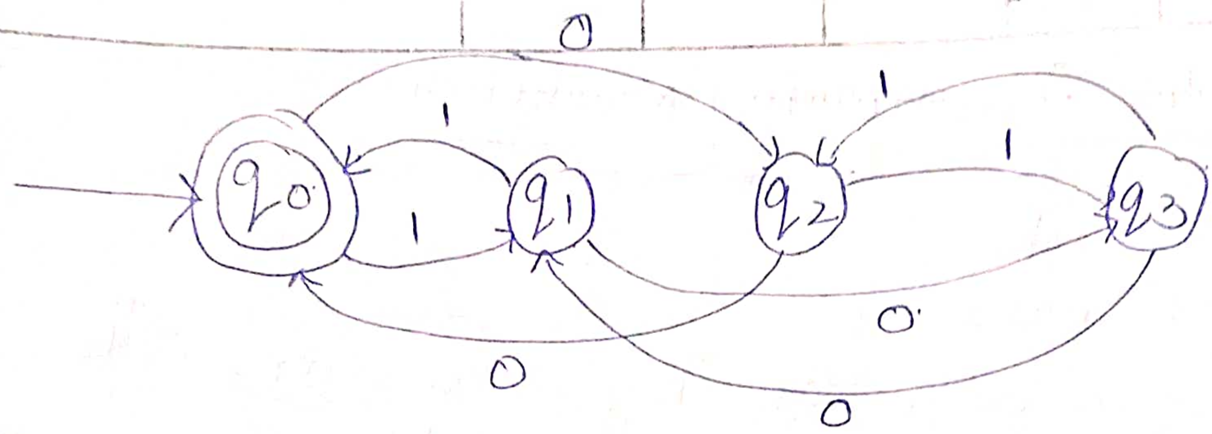
Q.

States	I/P 0	I/P 1
→ q_0	q_2	q_1
q_1	q_3	q_0
q_2	q_0	q_3
q_3	q_1	q_2

String given

110101

① STD (State Transition Diagram)



② Tuples.

$M = (\{q_0, q_1, q_2, q_3\}, \{0, 1\}, q_0, q_0)$

$\delta : Q \times \Sigma \rightarrow Q$

$q_0 \times 0 \rightarrow q_2$

$q_0 \times 1 \rightarrow q_1$

$q_1 \times 0 \rightarrow q_3$

$q_1 \times 1 \rightarrow q_0$

$q_2 \times 0 \rightarrow q_0$

$q_2 \times 1 \rightarrow q_3$

$q_3 \times 0 \rightarrow q_1$

$q_3 \times 1 \rightarrow q_2$

③ 110101

$\rightarrow q_0 \cdot 1 \rightarrow q_1$

$q_1 \cdot 1 \rightarrow q_0$

$q_0 \cdot 0 \rightarrow q_2$

$q_2 \cdot 1 \rightarrow q_3$

$q_3 \cdot 0 \rightarrow q_1$

$q_1 \cdot 1 \rightarrow q_0$

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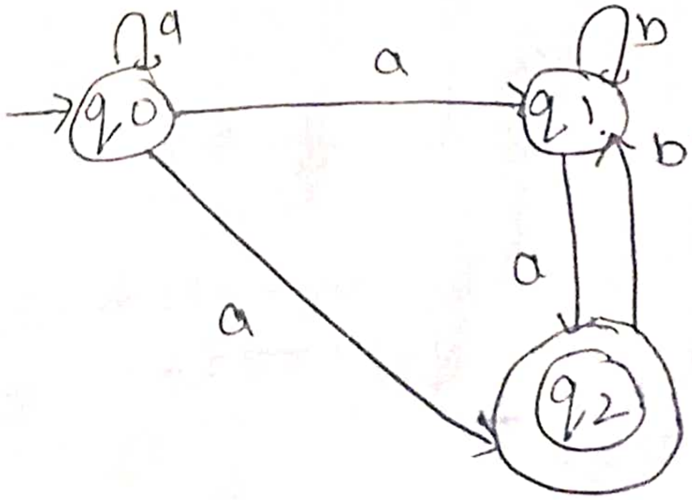
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

This Machine as the we Reached final state. 'q0' with all intial string and strings. Ends therefore string is Acceptable.

⇒ string is acceptable as string Ends and F.S. reaches.

Q°



(i) aabbb
(ii) aaa
(iii) aba.

States	q|0	
	a	b
→q0	q0,q1, q2	–
q1	q2	q1
q2	–	q1

Main Ideas, Questions & Summary:

Library / Website Ref.:-

Tupples

$M = (\{q_0, q_1, q_2\}, \{a, b\}, q_0, q_2)$

(i) <u>aabbb</u>

$q_0 \cdot a \rightarrow q_1$	$q_0 \cdot a \rightarrow q_0$	$q_0 \cdot a \rightarrow q_2$
$q_1 \cdot a \rightarrow q_2$		
$q_2 \cdot b \rightarrow q_1$		
$q_1 \cdot b \rightarrow q_1$		
$q_1 \cdot b \rightarrow q_1$		

(ii) <u>aaa</u>

$q_0 \cdot a \rightarrow q_0$	$q_0 \cdot a \rightarrow q_1$	$q_0 \cdot a \rightarrow q_2$
$q_0 \cdot a \rightarrow q_1$	$q_1 \cdot a \rightarrow q_2$	
$q_1 \cdot a \rightarrow q_2$		S.N.A
S.A	S.N.A	

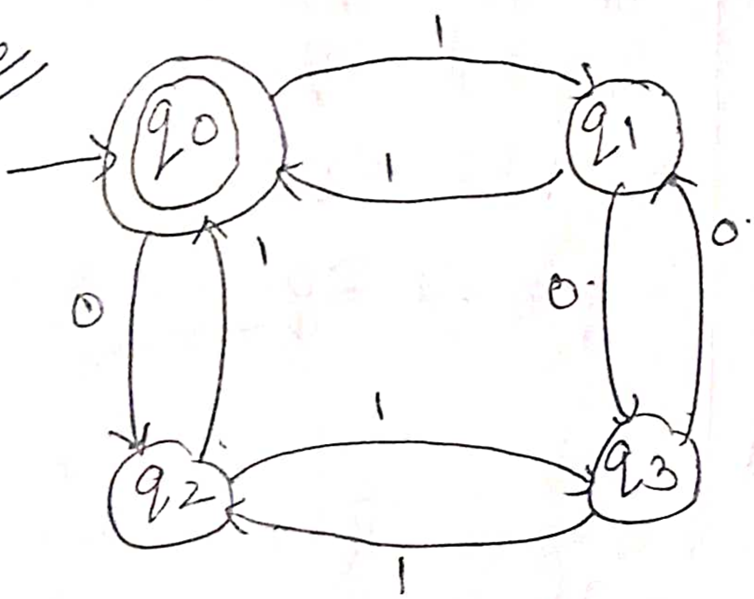
(iii) <u>aba</u>

$q_0 \cdot a \rightarrow q_1$	$q_0 \cdot a \rightarrow q_0$	$q_0 \cdot a \rightarrow q_2$
$q_1 \cdot b \rightarrow q_1$	S.N.A	$q_2 \cdot b \rightarrow q_1$
$q_1 \cdot a \rightarrow q_2$.		$q_1 \cdot a \rightarrow q_2$

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Qo



Determine whether the following string can be accepted by the Automata or not

(i) 101101

(ii) 11101

States	0	1
q0	q2	q1
q1	q0	q3
q2	-	q0, q3
q3	q1	q2

Main Ideas, Questions & Summary:

Library / Website Ref.:-

101101

$q_0 \cdot 1 \rightarrow q_1$

$q_1 \cdot 0 \rightarrow q_3$

$q_3 \cdot 1 \rightarrow q_2$

$q_2 \cdot 1 \rightarrow q_0$

$q_0 \cdot 0 \rightarrow q_2$

$q_2 \cdot 1 \rightarrow q_0$

S. A

11101

$q_0 \cdot 1 \rightarrow q_1$

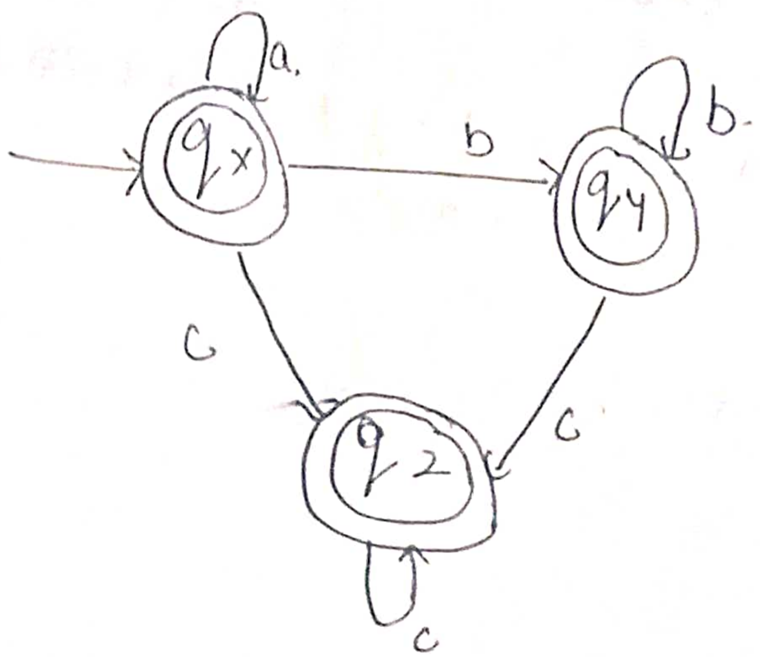
$q_1 \cdot 1 \rightarrow q_0$

$q_0 \cdot 1 \rightarrow q_1$

$q_1 \cdot 0 \rightarrow q_3$

$q_3 \cdot 1 \rightarrow q_2$

Q.



(i) abc

(ii) abcab

(iii) abb

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Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

(i) abc

$q_x \cdot a \rightarrow q_y$

$q_y \cdot b \rightarrow q_y$

$q_y \cdot c \rightarrow q_2$

(ii) abcab

$q_x \cdot a \rightarrow q_y$

$q_y \cdot b \rightarrow q_y$

$q_y \cdot c \rightarrow q_2$

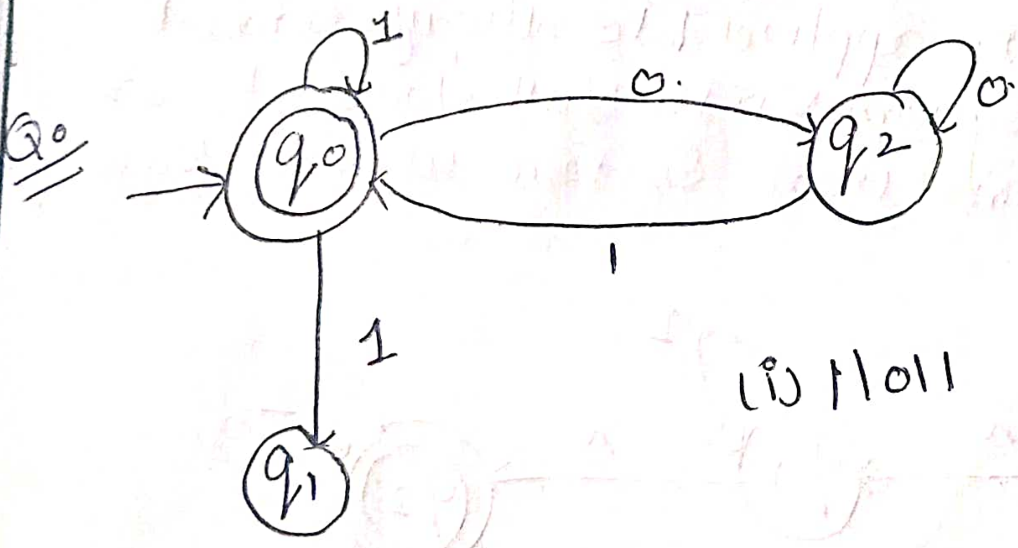
S.N.A

abb

$q_x \cdot a \rightarrow q_y$

$q_y \cdot b \rightarrow q_y$

$q_y \cdot b \rightarrow q_y$



(i) 11011

Solⁿ

11011

$q_0 \cdot 1 \rightarrow q_0$

$q_0 \cdot 1 \rightarrow q_0$

$q_0 \cdot 0 \rightarrow q_2$

$q_2 \cdot 1 \rightarrow q_0$

$q_0 \cdot 1 \rightarrow q_0$

S.A

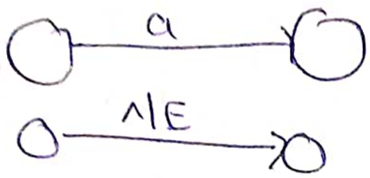
Main Ideas, Questions & Summary:

Library / Website Ref.:-

Transition Containing Null Moves (^)

⇒ That Edge which doesnot Contain any Value is Called Null.

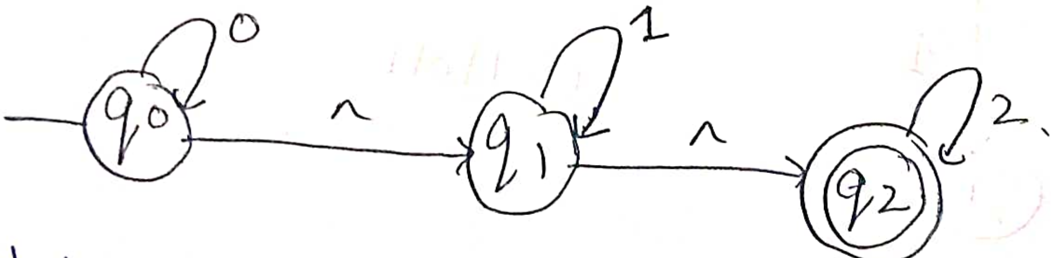
⇒



⇒ It is Represented by "^|E".

⇒ When No input is applied We always Convert the Transition System with Null Nodes to an Equivalent Transition System without Null moves

Q.



We have to Eliminate the Null Move.

⇒ Rules:-

(i) find out all the Null Nodes.

(ii) find the outgoing Edges of V_2 Vertex

V_2 Vertex → outgoing Edges

(iii) duplicate by V_1 originating (duplicate, V_1 originating

(iv.1) If V_1 is intial state then make V_2 intial state (If V_1 is I.S, then make V_2 I.S)

H.2) If V_2 is final state then make V_1 final state. (If V_2 is FoS, then make V_1 FoS)

Soln: $q_0 \xrightarrow{\wedge} q_1$ (I).

(1) $\delta(q_0, \wedge) \to q_1$

$q_0 \downarrow V_1$, $q_1 \downarrow V_2$

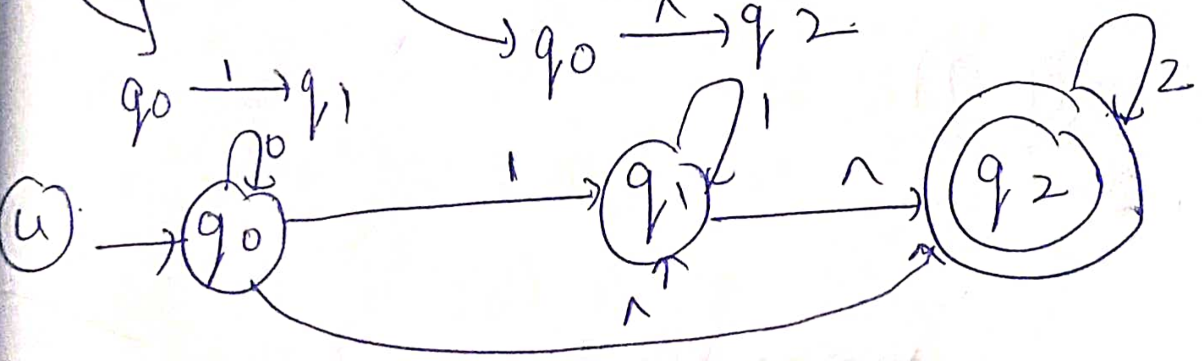
(2) V_2 vertex - outgoing edges

$q_1 \xrightarrow{1} q_1$, $q_1 \xrightarrow{\wedge} q_2$.

(3) - duplicate V_1 originating

$q_0 \xrightarrow{1} q_1$ $q_0 \xrightarrow{\wedge} q_2$

(4)



(1) $\delta(q_1, \wedge) \rightarrow q_2$

$q_1 \downarrow V_1$, $q_2 \downarrow V_2$

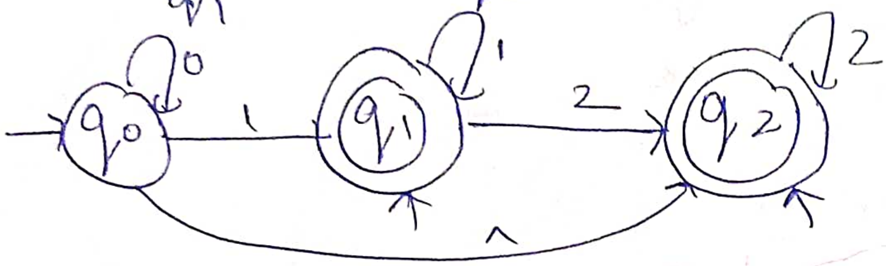
(2) V_2 vertex - outgoing Edges

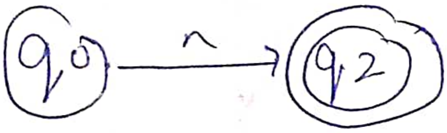
$q_2 \xrightarrow{2} q_2$

(3) duplicate V_1 originating

$q_1 \xrightarrow{2} q_2$

(4)





(1) $\delta(q_0, \wedge) \rightarrow q_2$

$q_0 \downarrow V_1$, $q_2 \downarrow V_2$

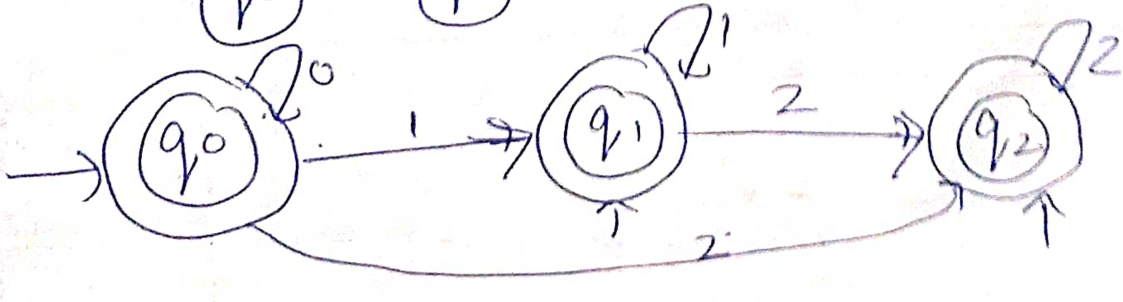
(2) V_2-vector - outgoing Edges.

$q_2 \xrightarrow{2} q_2$

(3) Duplicate

$q_0 \xrightarrow{2} q_2$

(4)



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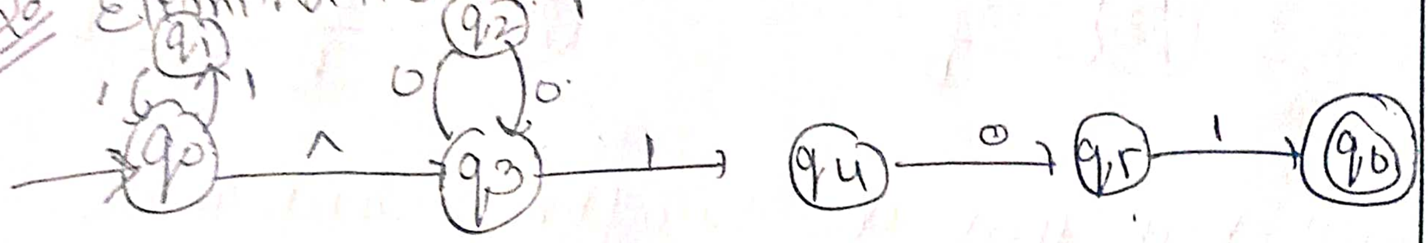
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

NOTE:- * There canbe more than Initial state if we are removing Null states

Q. Elimination of Null Moves.



Soln $q_0 \xrightarrow{\wedge} q_3$

1) $\delta(q_0, \wedge) \longrightarrow q_3$

$\delta(q_0, \wedge)$ ↓ V_1; q_3 ↓ V_2

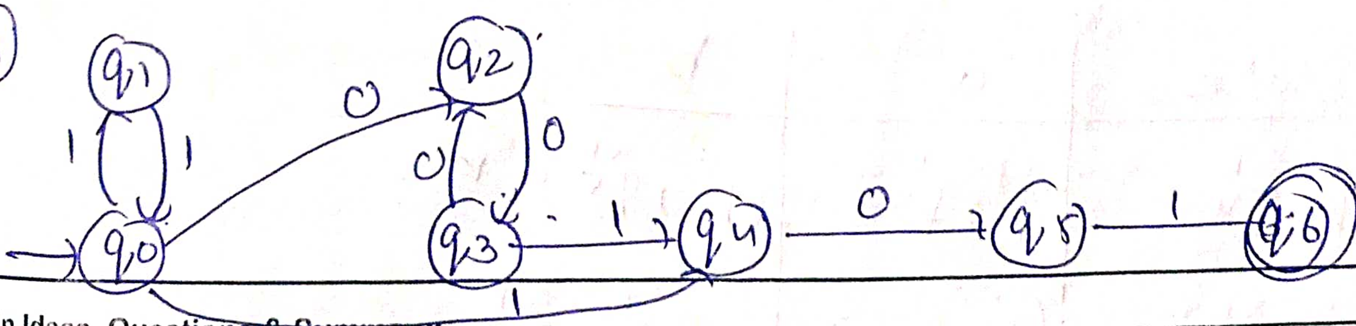
2) outgoing from V_2.

$q_3 \xrightarrow{0} q_2$ $\qquad$ $q_3 \xrightarrow{1} q_4$

3) Duplicate.

$q_0 \xrightarrow{0} q_2$ $\qquad$ $q_0 \xrightarrow{1} q_4$

4)

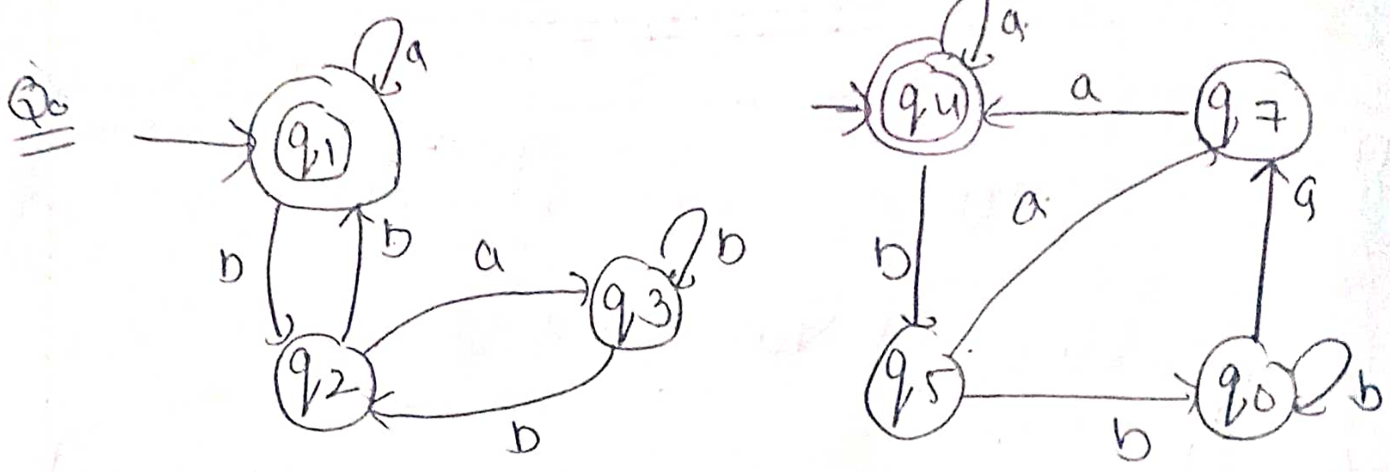


Main Ideas, Questions & Summary:

Library / Website Ref.:-

Equivalance of finite Automata

Q6.



Will check that the two finite automata are Equivalent or not.

grouping — final State (F, F) ✓

grouping — Non-final State (NF, NF) ✓

(F, NF) · ✗

Transition Table

States	a	b
(q_1^{F}, q_4^{F})	(q_1^{F}, q_4^{F}) ✓	(q_2^{NF}, q_5^{NF}) ✓
(q_2^{NF}, q_5^{NF})	(q_3, q_7) ✓	$(q_1^{F}, q_6^{NF}$ ✗

∴ So these Automata's are Non Equivalent Automata

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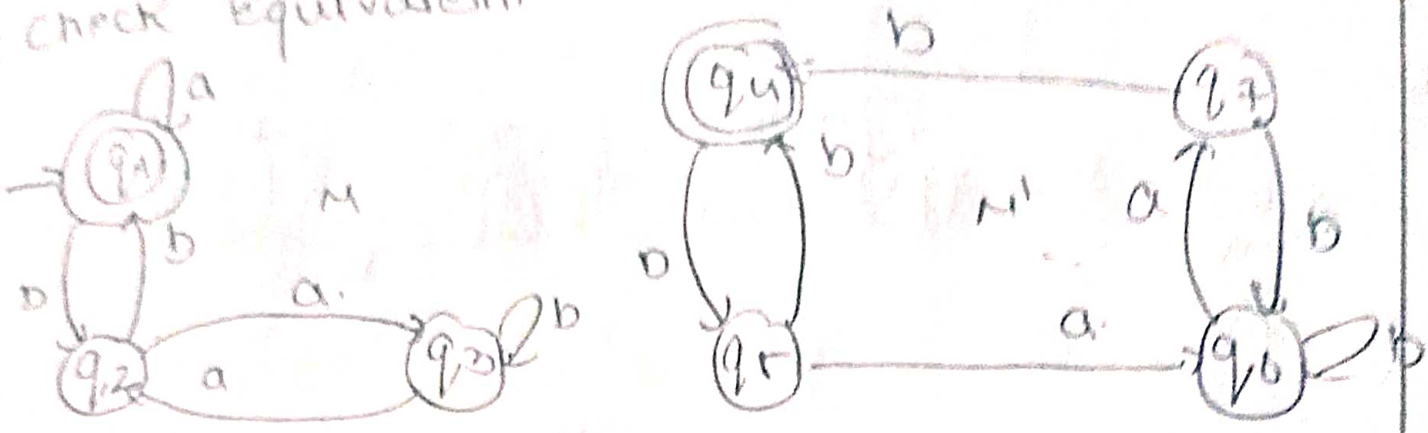
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Q. Check Equivalent



Transition Table

States	a	b
(q_1^F, q_4^F)	(q_1^F, q_4^F)	(q_2^{NF}, q_5^{NF}) ✓
(q_2^{NF}, q_5^{NF})	(q_3^{NF}, q_6^{NF})	(q_1^F, q_4^F) ✓
(q_3^{NF}, q_6^{NF})	(q_2^{NF}, q_7^{NF})	(q_3^{NF}, q_6^{NF})
(q_2^{NF}, q_7^{NF})	(q_3^{NF}, q_6^{NF})	(q_1^F, q_4^F)

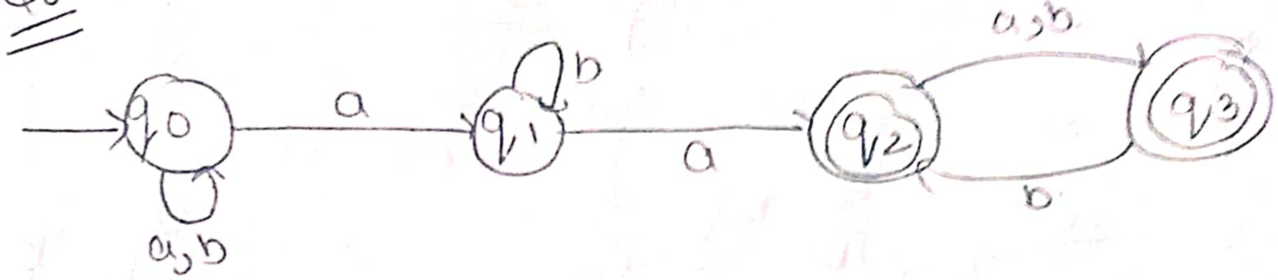
∴ All the states are covered at the time. and no new state were recieved so. Table Ends and finall the conditions of Table Entry Were statisfy the condition of equivalence. So the finite automato M and M' are. Equivalent

Main Ideas, Questions & Summary:

Library / Website Ref.:-

Conversion of NDFA to DFA

Q0



Step 1 :- State Transition diagram → State Transition Table

States	input a	input b
→ q0	{q0, q1}	q0
q1	q2	q1
q2	q3	q3
q3	ϕ	q2

Step-2 :- Define Tuples.

$Q = \{q0, q1, q2, q3\}$

$\Sigma \to a, b$

I.S → q0

F.S → q2, q3.

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Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

$\delta: Q \times \Sigma \rightarrow 2^Q \rightarrow 2^4 \rightarrow 16.$

$\phi, q_0, q_1, q_2, q_3.$

$\{q_0, q_1\}, \{q_0, q_2\}\ \{q_0, q_3\}$

$\{q_1, q_2\}\ \{q_1, q_3\}\ \{q_2, q_3\}.$

$\{q_0, q_1, q_2\}\ \{q_0, q_1, q_3\}.$

$\{q_1, q_2, q_3\}\ \{q_0\ q_2, q_3\}$

$\{q_0, q_1, q_2, q_3\}$

I.S $\rightarrow q_0.$

$\delta(q_0, a) \rightarrow \{q_0, q_1\}$ * Newstate

$\delta(q_0, b) \rightarrow q_0.$

$\delta(\{q_0, q_1\}, a) \rightarrow \delta(q_0, a) \cup \delta(q_1, a)$

$\rightarrow \{q_0, q_1\} \cup \{q_2\}.$

$\rightarrow \{q_0, q_1, q_2\}$ * Newstate.

$\delta(\{q_0, q_1\}, b) \longrightarrow \delta(q_0, b) \cup \delta(q_1, b\}$

$\{q_0\} \cup \{q_1\}$

$\{q_0, q_1\}$

Main Ideas, Questions & Summary:

Library / Website Ref.:-

$\delta(\{q_0, q_1, q_2\}, a) = \delta(q_0, a) \cup \delta(q_1, a) \cup \delta(q_2, a)$
$= \{q_0, q_1\} \cup \{q_2\} \cup \{q_3\}$
$= \{q_0, q_1, q_2, q_3\}$ * New State

$\delta(\{q_0, q_1, q_2\}, b) = \delta(q_0, b) \cup \delta(q_1, b) \cup \delta(q_2, b)$
$= \{q_0\} \cup \{q_1\} \cup \{q_3\}$
$= \{q_0, q_1, q_3\}$ * New State.

$\delta(\{q_0, q_1, q_2, q_3\}, a) = \delta(q_0, a) \cup \delta(q_1, a) \cup \delta(q_2, a) \cup \delta(q_3, a)$
$= \{q_0, q_1\} \cup \{q_2\} \cup \{q_3\} \cup \{\phi\}$
$= \{q_0, q_1, q_2, q_3\}$

$\delta(\{q_0, q_1, q_2, q_3\}, a) = \delta(q_0, b) \cup \delta(q_1, b) \cup \delta(q_2, b) \cup \delta(q_3$
$= \{q_0\} \cup \{q_1\} \cup \{q_3\} \cup \{q_2\}$
$= \{q_0, q_1, q_2, q_3\}$.

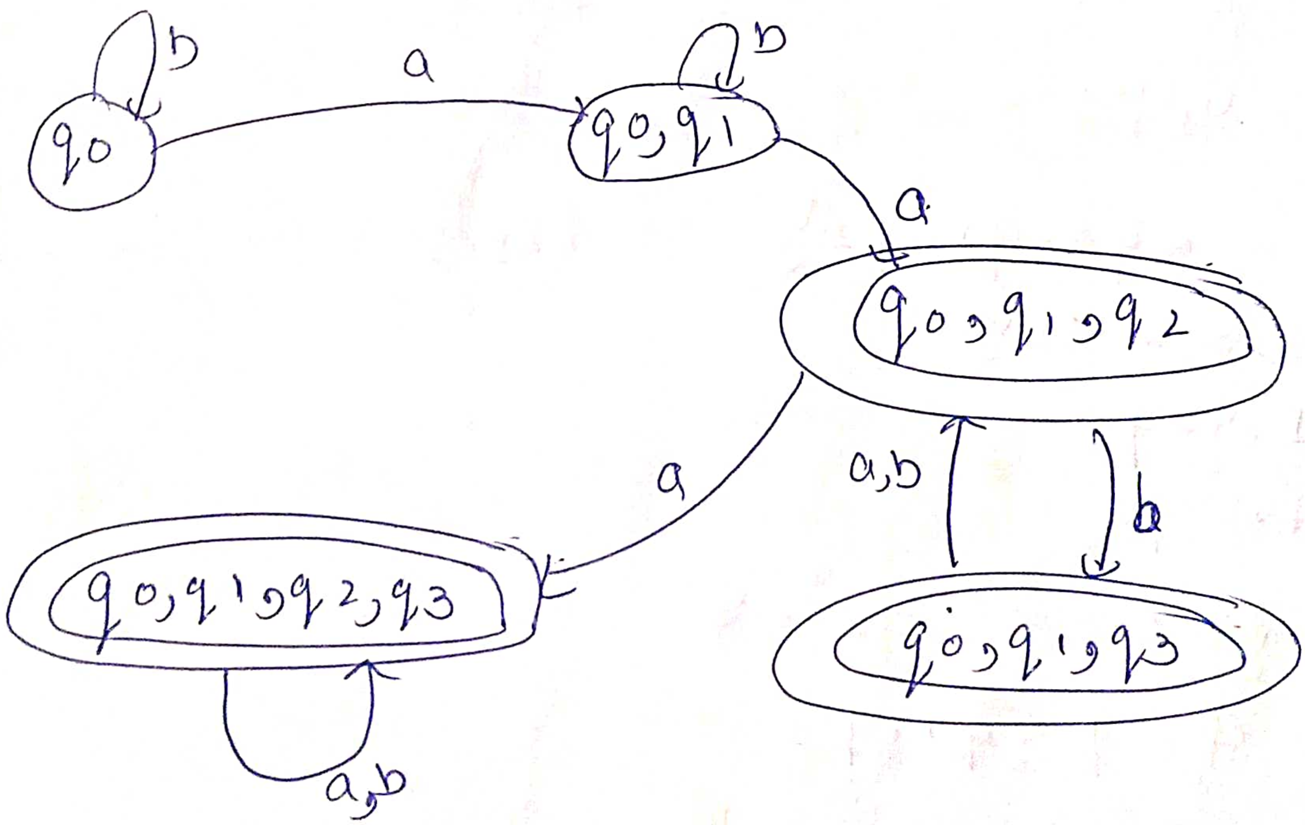
$\delta(\{q_0, q_1, q_3\}, a) = \delta(q_0, a) \cup \delta(q_1, a) \cup \delta(q_3, a)$
$= \{q_0, q_1\} \cup \{q_2\} \cup \{\phi\}$
$= \{q_0, q_1, q_2\}$

$\delta(\{q_0, q_1, q_3\}, b) = \delta(q_0, b) \cup \delta(q_1, b) \cup \delta(q_3, b\}$
$= \{q_0\} \cup \{q_1\} \cup \{q_2\}$
$= \{q_0, q_1, q_2\}$

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Present State	Input a	Input b
q_0	$\{q_0, q_1\}$	$\{q_0$
$\{q_0, q_1, q_2\}$	$\{q_0, q_1, q_2, q_3\}$	$\{q_0, q_1, q_3\}$
$\{q_0, q_1, q_2, q_3\}$	$\{q_0, q_1, q_2, q_3\}$	$\{q_0, q_1, q_2, q_3\}$
$\{q_0, q_1, q_3\}$	$\{q_0, q_1, q_2\}$	$\{q_0, q_1, q_2\}$



Main Ideas, Questions & Summary:

Library / Website Ref.:-

Q. Given NDFA is:-

$S \mid \Sigma$	input a	input b
$\rightarrow q_0$	$\{q_0, q_1\}$	$\{q_2$
q_1	$\{q_0\}$	$\{q_1\}$
$*q_2$	ϕ	$\{q_0, q_1\}$

Convert it into DFA.

Solun

Tuples

$Q = \{q_0, q_1, q_2\}$.

$\Sigma = \{a, b\}$

$I.S = q_0$

$F.S = q_2$

$\delta: Q \times \Sigma = 2^Q = 2^3 = 8$

ϕ, q_0, q_1, q_2.

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

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

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

I.S $\rightarrow q_0$

$\delta(q_0, a) \longrightarrow \{q_0, q_1\}$ * New State

$\delta(q_0, b) \longrightarrow q_2$

$\delta(\{q_0, q_1\}, a\} \rightarrow \delta\{q_0, a\} \cup \delta\{q_1, a\}$

$\rightarrow \{q_0, q_1\} \cup \{q_0\}$

$\Rightarrow \{q_0, q_1\}$

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

$\Rightarrow \{q_2\} \cup \{q_1\}$

$\Rightarrow \{q_2, q_1\}$ * New State.

$\delta(\{q_2, q_1\}, a) = \delta\{q_2, a\} \cup \delta(q_1, a)$

$= \phi \cup \{q_0\}$

$= \{q_0\}$

Main Ideas, Questions & Summary:

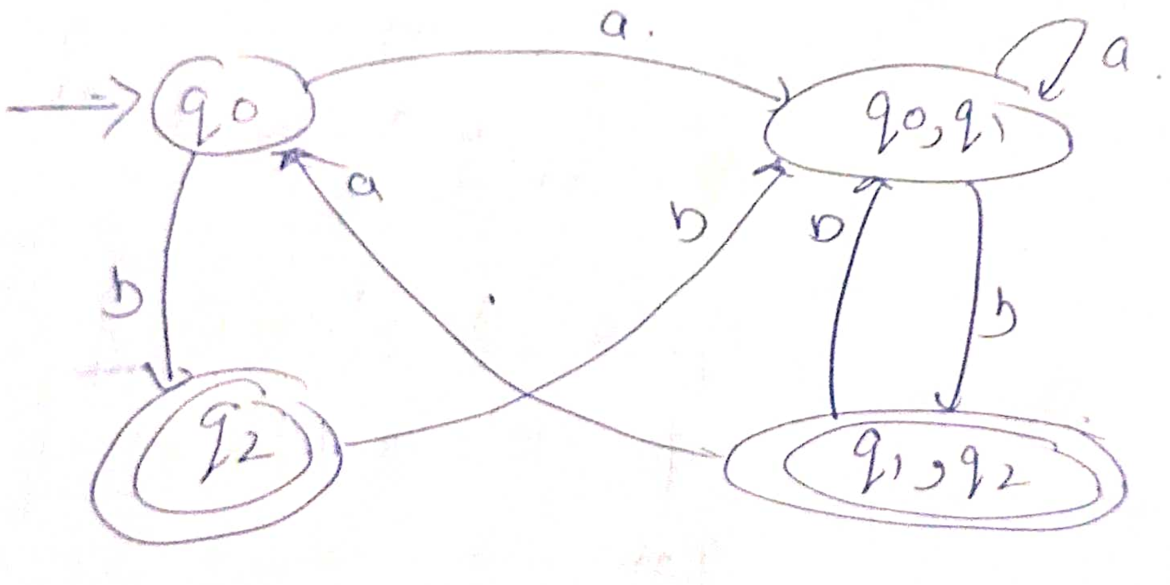
Library / Website Ref.:-

$$\delta(\{q_0, q_1\}, b) = \delta(q_0, b) \cup \delta(q_1, b)$$

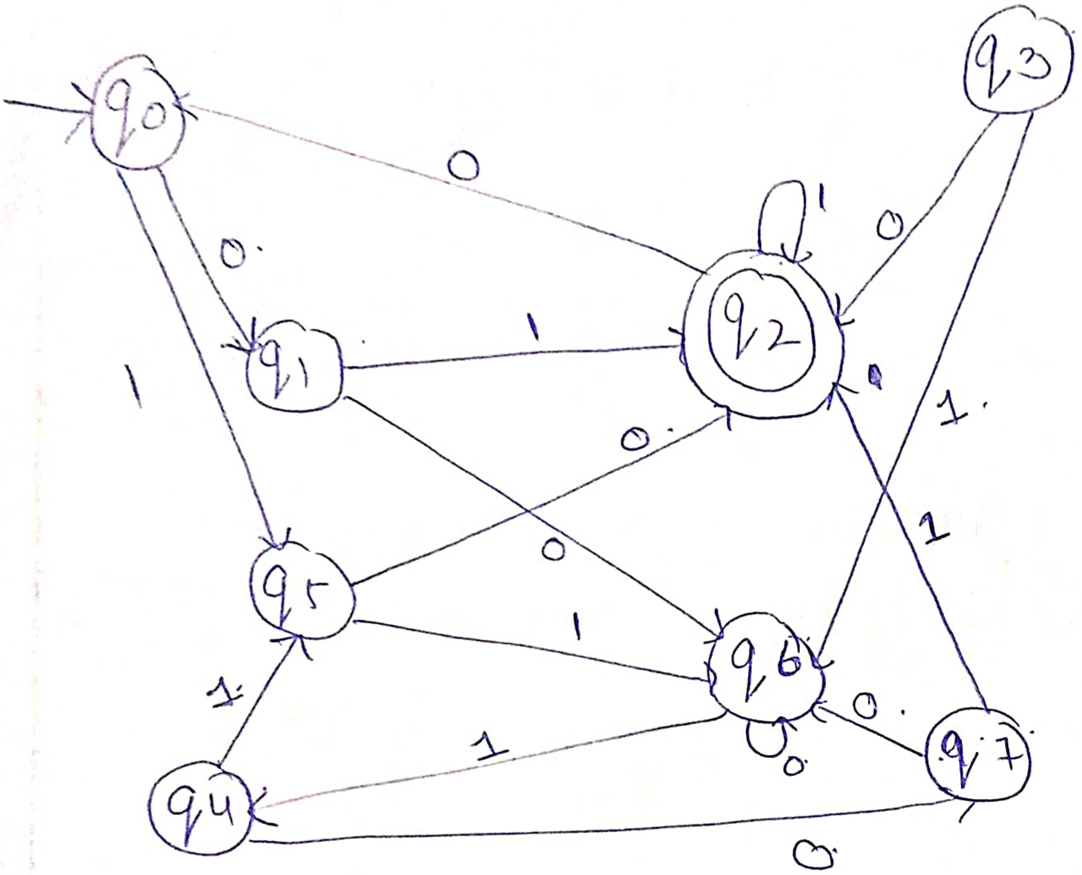
$$= \{q_0, q_1\} \cup \{q_1\}$$

$$= \{q_0, q_1\}$$

Present	Input a	Input b
$\rightarrow q_0$	$\{q_0, q_1\}$	q_2
$\{q_0, q_1\}$	$\{q_0, q_1\}$	$\{q_1, q_2\}$
$\{q_1, q_2\}$	$\{q_0\}$	$\{q_1, q_2\}$
q_2	ϕ	$\{q_0, q_1\}$



Minimization of Finite Automata



States	Inputs 0	Inputs 1
→ q_0	q_1	q_5
q_1	q_6	q_2
q_2	q_0	q_2
q_3	q_2	q_6
q_4	q_7	q_5
q_5	q_2	q_6
q_6	q_6	q_4
q_7	q_6	q_2

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Tupples Step-2

$M = (Q, \Sigma, \delta, I.S, F.S)$

$Q = \{q_0, q_1, q_2, q_3, q_4, q_5, q_6, q_7\}$

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

$I.S = q_0$

$F.S = q_2$

Step-3

$\pi_0 \longrightarrow$ grouping $\rightarrow$ F.S / $\rightarrow$ N.F.S

$\pi_0 = \{q_2\}\{q_0, q_1, q_3, q_4, q_5, q_6, q_7\}.$

$\left.\begin{array}{l}\delta(q_0, 0) = q_1 \\ \delta(q_1, 0) = q_6\end{array}\right]$ ✓ $\left.\begin{array}{l}\delta(q_0, 1) = q_5 \\ \delta(q_1, 1) = q_2\end{array}\right]$ ×

$\left.\begin{array}{l}\delta(q_0, 0) = q_1 \\ \delta(q_3, 0) = q_2\end{array}\right]$ ×

Main Ideas, Questions & Summary:

Library / Website Ref.:-

$\delta(q_4, 0) = q_7$ ✓ $\quad \delta(q_0, 1) = q_5$, $\delta(q_4, 1) = q_5$ ✓

$\delta(q_0, 0) = q_1$
$\delta(q_5, 0) = q_2$ ×

$\delta(q_0, 0) = q_1$, $\delta(q_6, 0) = q_6$ ✓ $\quad \delta(q_0, 1) = q_5$, $\delta(q_6, 1) = q_4$ ✓

$\delta(q_0, 0) = q_1$, $\delta(q_7, 0) = q_6$ ✓ $\quad \delta(q_0, 1) = q_5$, $\delta(q_7, 1) = q_2$ ×

$\pi_2 = \{q_2\}, \{q_0, q_4, q_6\}, \{q_1, q_3, q_5, q_7\}$.

Note: No of states more paring will be done first

$\delta(q_1, 0) = q_6$
$\delta(q_3, 0) = q_2$ ×

$\delta(q_1, 0) = q_6$
$\delta(q_5, 0) = q_2$ ×

$\delta(q_1, 0) = q_6$, $\delta(q_7, 0) = q_6$ ✓ $\quad \delta(q_1, 1) = q_2$, $\delta(q_7, 1)\ q_2$ ✓

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

$\Pi_2 = \{q_2\}, \{q_0, q_4, q_6\}, \{q_1, q_7\}, \{q_3, q_5\}$

$\left.\begin{array}{l}\delta(q_0, 0) \Rightarrow q_1 \\ \delta(q_4, 0) \Rightarrow q_7\end{array}\right] \checkmark$ $\qquad$ $\left.\begin{array}{l}\delta(q_0, 1) \rightarrow q_5 \\ \delta(q_4, 1) \rightarrow q_5\end{array}\right] \checkmark$

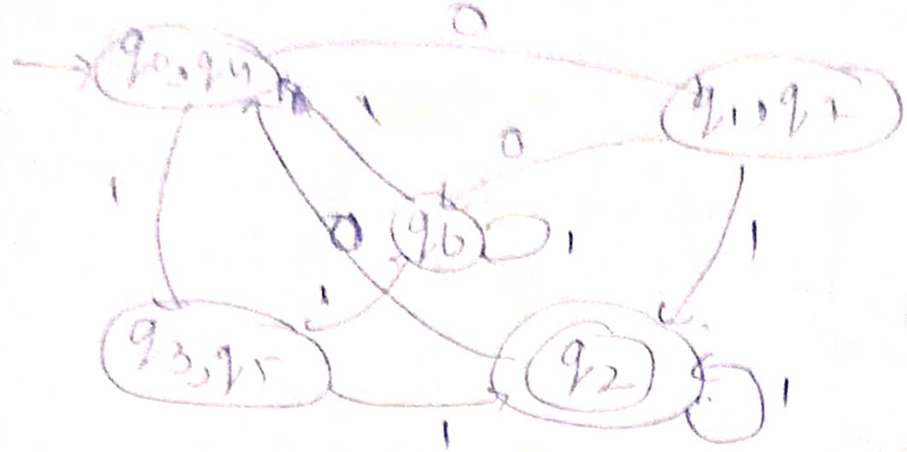
$\left.\begin{array}{l}\delta(q_0, 0) \Rightarrow q_1 \\ \delta(q_6, 0) \Rightarrow q_6\end{array}\right] \times$

$\Pi_3 = \{q_2\}, \underbrace{\{q_0, q_4\}}_{q_0}, \{q_6\}, \underbrace{\{q_1, q_7\}}_{q_1}, \underbrace{\{q_3, q_5\}}_{q_3}$

P.S	0	1
→[q0, q4]	[q1, q7]	[q3, q5]
[q1, q7]	[q6]	[q2]
(q2)	[q0, q4]	[q2]
[q3, q5]	[q2]	[q6]
[q6]	[q6]	[q0, q4]

Main Ideas, Questions & Summary:

Library / Website Ref.:-



Regular Expression

⇒ A Regular Expression is used to define a language

⇒ Language :- A language is a set of strings involving the symbols from some alphabets.

Symbols :- Every thing in mathematics is based on symbol. A symbol is in abstract Entity.

Alphabets :- An alphabet is a finite non-Empty set. Of symbols

String :- It is a sequence of symbols or we say that a string is a finite or infinite sequence of symbols selected from some alphates

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Regular Expression.

↓

Language

↓

Symbols & Alphates

↓

*, #, $

- Decimal Alphas (0 - - - 9)
- Binary Alphets (0 - - - 1)

] Digits (0 - - 9)

- English Alphats (a - - - z), (A - - - z)

Language! - It is also the collection of strings Constructed from a finite alphabets of. symbols.

Definition of Regular Expression: (1) Every primitive Regular Expression.

is a Regular Expression

Main Ideas, Questions & Summary:

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Primitive Regular Expression :- (i) x, $\forall x \in \Sigma$
(ii) Λ, Empty string.
(iii) ϕ, no string in the particular language

② If R_1 & R_2 are the Regular Expressions then
$R_1 + R_2$ (Union) $\longrightarrow$ Regular Expression.
Concatination of R_1 & R_2 $\longrightarrow$ Regular Expression

R_1 & R_2 $\longrightarrow$ RE
$R_1 + R_2$ (Union) $\longrightarrow$ RE
$R_1 R_2$ (concatination) $\longrightarrow$ RE

③ The Difference of Two Regular Expression is a Regular Expression.

④ The Complement of a Regular Expression is a Regular Expression.

⑤ If R is a Regular Expression than R^* (R closure) is also a Regular Expression

$R \longrightarrow$ RE
R^* (R closer) $\longrightarrow$ RE

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Notations :-

① $(x) \rightarrow$ It will Read as a "grouping of x".

② x^* (x closure) $\rightarrow$ This also known as 'postfix star' & It is also known as 'Kleen closure'.

It means zero or more occurence of a preceeding Regular Expression

a^*

$\{\wedge, a, aa, aaa, aaaa, aaaaa \text{------} \}$.

③ $x \overset{\text{and}}{\cdot} y \rightarrow$ Read as "x and y" $\rightarrow$ Concatenation. Read as just as a position of x and y.

④ $x \overset{\text{or}}{+} y \rightarrow$ Union $\rightarrow$ Read as 'Either x or y'.

⑤ $x^+ \longrightarrow$ closure $\rightarrow$ Read as . one or more occurence of x.

$x^+ = \{x, xx, xxx \text{---}\}$

⑥ $(\wedge + x)$ or $(x + \wedge)$ Read as zero or one occurrence of x but atleast $1x$.

Main Ideas, Questions & Summary:

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$\{\Lambda, 0, 1, 10, 01, 1010, 0101, 1111010 \ldots\ldots\}$

Identity Rules for Regular Expression

* Suppose Q, P & R are the Regular Expression then following Identities hold for the Regular Expression.

① $\phi + R = R$

② $\phi R + R\phi = \phi$

③ $\Lambda R = R\Lambda = R$.

④ $\Lambda^* = \Lambda$ and $\phi^* = \Lambda$.

⑤ $R + R = R$

⑥ $R^* R^* = R^*$

⑦ $RR^* = R^* R$.

⑧ $(R^*)^* = R^*$

⑨ $\Lambda + RR^* = R^* = \Lambda + R^* R$

⑩ $(PQ)^* P = P(QP)^*$

⑪ $(P+Q)^* = (P^* Q^*)^* = (P^* + Q^*)^*$

⑫ $(P+Q)R = PR + QR$ and $R(P+Q) = RP + RQ$

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Q. $\Sigma = \{0\}$ with the Even no of zeros

$\{\wedge, 00, 0000, 000000, \text{-------}\}$

$\rightarrow (00)^*$

Q. $\Sigma = \{1\}$ Even no of ones

$\{\wedge, 11, 1111, 111111, \text{----}\}$.

$\rightarrow (11)^*$

Q. $\Sigma = \{1\} \rightarrow$ any no of ones.

$\{\wedge, 1, 11, 111, 1111 \text{------}\}$

$\rightarrow (1)^*$

Q. $\Sigma = \{0, 1\} \rightarrow$ Even no of zero.

$\{\wedge, 100, 00001, 1100, 10101, 1010101, \text{----}\}$.

$\rightarrow (001)^*$

Q. $\Sigma = \{0, 1\} \rightarrow$ string Ends with 00

$(0+1)^* 00 \rightarrow$ Regular Expression

or

$(1+0)^* 00 \rightarrow$ Regular Expression.

Ideas, Questions & Summary:

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{1000, 11000, 00 - - - - - - - - }

Q. String having atleast 2 1's over the set $\Sigma = \{0, 1\}$

{^, 011, 1001, 11, 0101, 010111, 111100 - - -

$(0+1)^* 11$

Q. Any number of 0's & 1's Except null $\Sigma = \{0, 1\}$

{01, 101, 1110, 001, 110, 00, - - - - - - }

Q. Any number of a's followed by any no. of b's followed by any number of c's $\Sigma = \{a, b, c\}$

{^, aab, abc, aabcc, ac, bc, aac, acc.

$(a^* b^* c^*) \rightarrow$ Regular Expression

Q. Atleast a is followed by atleast one b is followed by atleast one c.

$a^+ b^+ c^+ \rightarrow$ Regular Expression

{ abc, aabbcc, abbc - - - - - }

Q. String starts with 0 & ends with 1 $\Sigma \{0, 1\}$

{ 001011, 01, 001, 011, 010101, 011001, - - }

$0 (0+1)^* 1 \rightarrow$ Regular Expression

Q. A language containing All strings having any no. of zeros and ones except null string.

$(0+1)^+ \rightarrow$ Regular Expression

Q. String in which the third character from Right is always 0 over the string $\Sigma = \{0,1\}$

$\cancel{\quad}(0+1)^*$ 0 0 or 1 0 or 1

$\Downarrow$

$(0+1)^* \, 0 \, (0+1) \, (0+1)$

Q. String having atleast Two one's over $\Sigma = \{0,1\}$.

$(0+1)^* \, 1 \, (0+1)^* \, 1 \, (0+1)^* \rightarrow$ Regular Expression.

Construction of Regular Expression

(1) Minimum Condition Satisfy.

~~Q. String in which~~

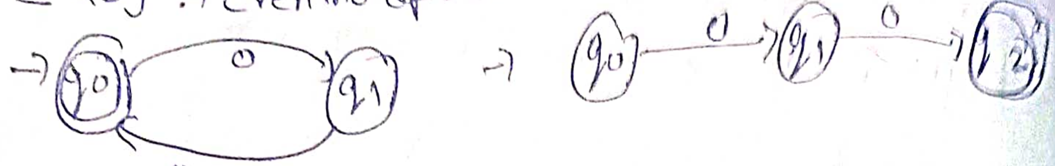
Q. Set of All strings over $\Sigma = \{a, b\}$ in which the number of occurrence ~~of~~ of a is divisible by 3.

All strings begining and Ending with 01 or 10
(01+10) (0+1)* + 1 (0+1)* (01+10)

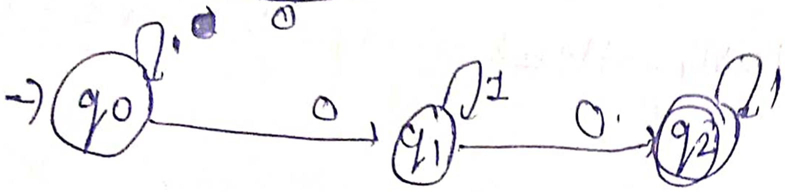
~~01 (0+1)* 01~~ ~~(01+10) (0+1)* (01+10)~~

Construction of DFA (Deterministic Finite automata)

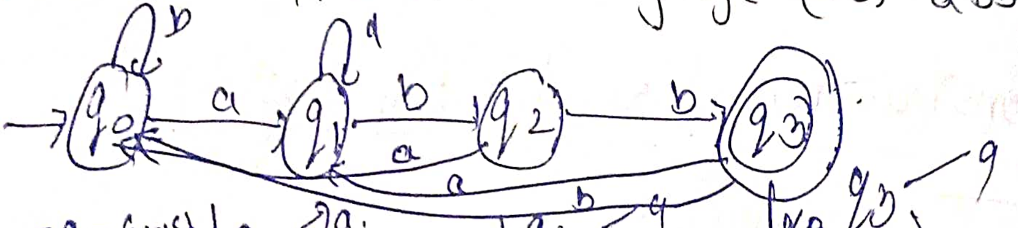
Q. Σ = {0} → Even no. of 0's.



Q. Σ = {0,1} → Even no. of 0's.



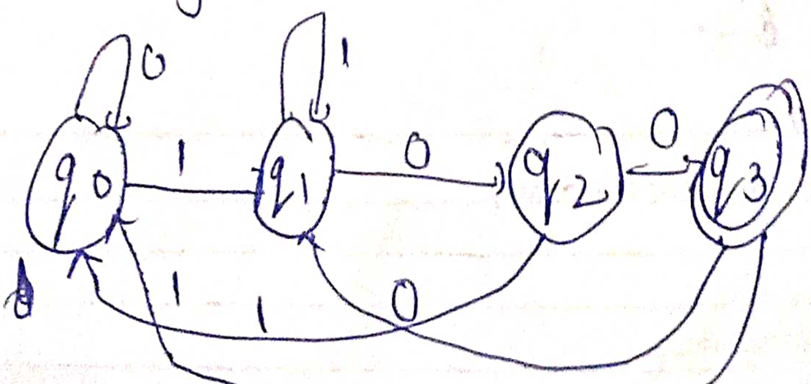
Q. Construct the DFA for the language '(a+b)* abb



q0 → a – Exist, → b | q1 → a, → b – Exit | q2 → a, → b – Exist | q3 → a, → b.

Q. Strings Ends with 00. Σ = {0,1}

(0+1)* 00 – Regular expression



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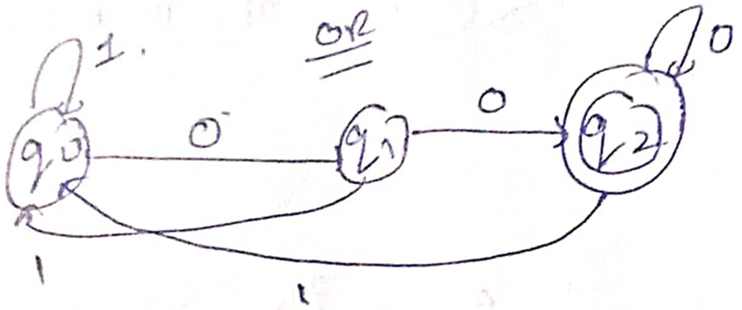
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

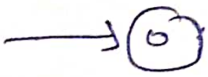


Construction of NDFA from RE

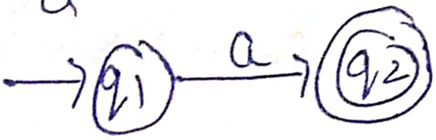
Rules:-

(1) $\wedge = \lambda = \epsilon$.

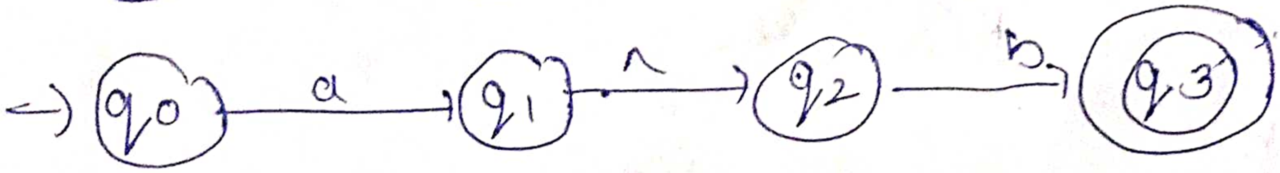
Or



(2) a



(3) Concatenation :- ~~(...)~~ (ab)



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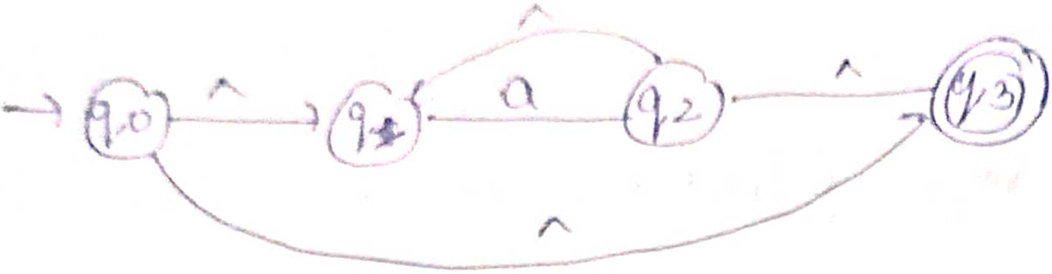
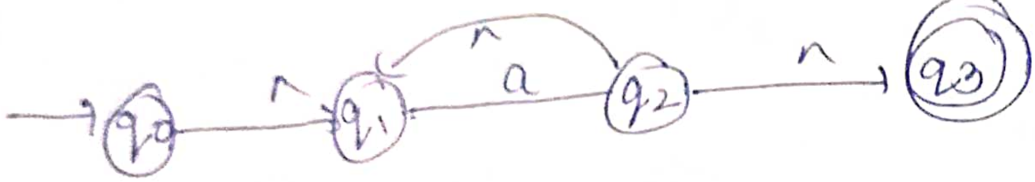
(4) Union $(a+b)$

(5) Kleen Star (a^*)



(6) Positive closure (a^+)



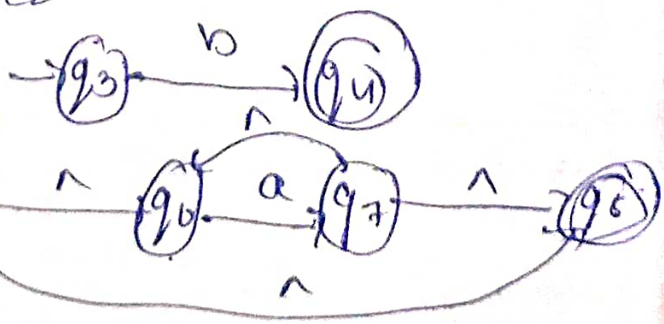
3) Regular Expression $b+ba^*$.
or
Construct the NDFA for the given Regular Expression.
$RE = b+ba^*$

Solun

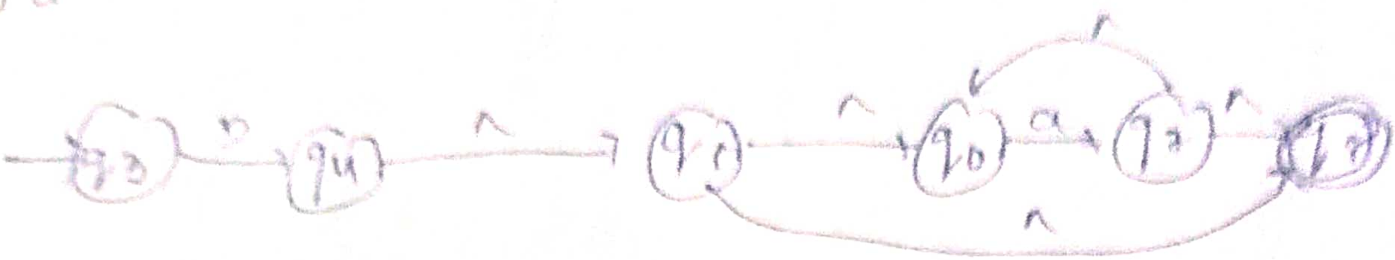
$$RE = \underbrace{b}_{RE_1} + \underbrace{ba^*}_{RE_2}$$

$RE_1 \rightarrow b$

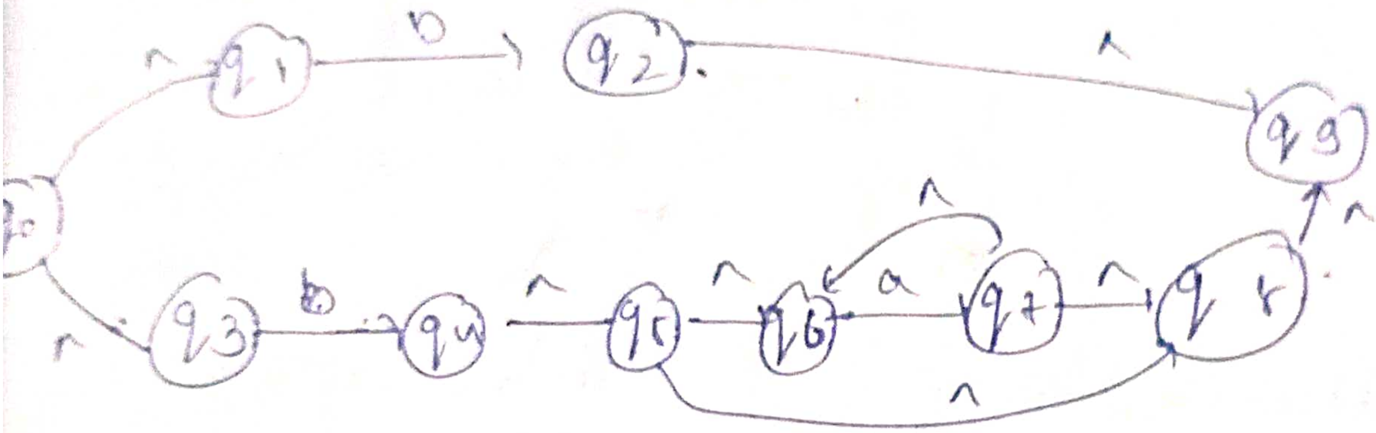
RE_2



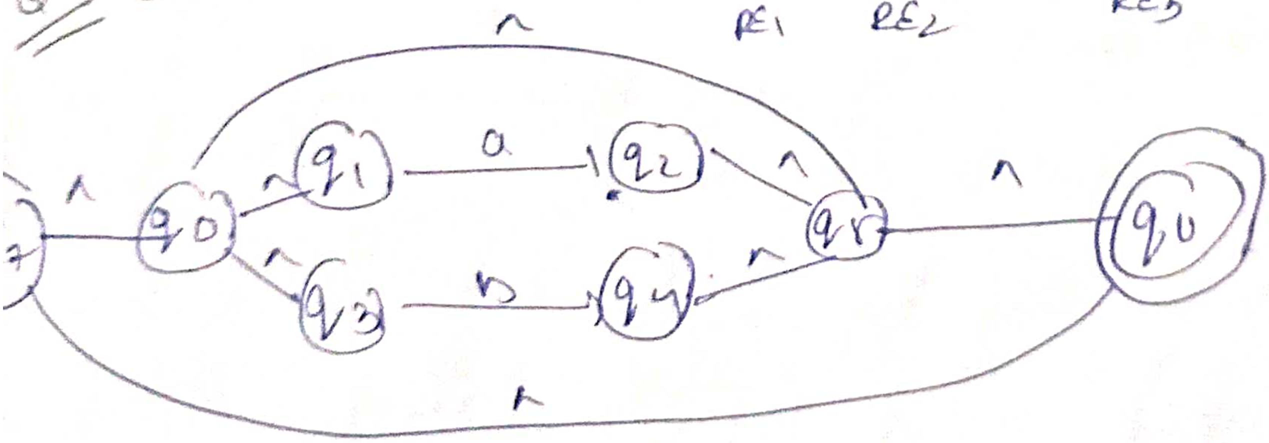
$b\,a^*$



$b + ba^*$



Q- Construct the NDFA for $\underbrace{a}_{RE_1} \cdot \underbrace{(a+b)^*}_{RE_2} \cdot \underbrace{ab}_{RE_3}$.



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Q:- Construct the DFA for even no. 1's & even no. of 0's.
for $\Sigma = \{0, 1\}$

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

Arden's Throrm

→ Diagram → RE

Theorm :- If P, Q, R are the Regular Expression over some input then R = Q + RP and the solution is $R = QP^*$

$P, Q \rightarrow RE.$

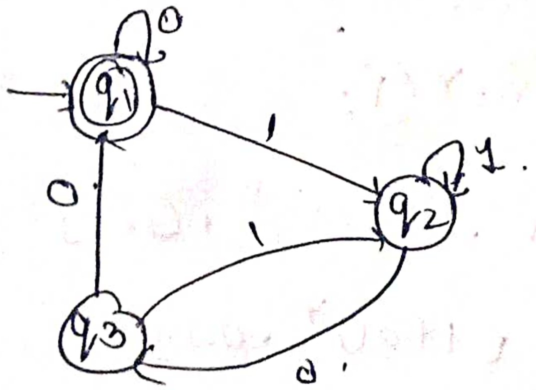
$R = Q + RP.$ — ①

solun $R = QP^*$ — ②

final state → Ans.

Find out the incomming Edges with Their input at each state.

Q Design a Regular Expression for the Corresponding DFA.



Main Ideas, Questions & Summary:

Library / Website Ref.:-

$q_1 = \wedge + q_1 \cdot 0 + q_3 \cdot 0$ (1)

$q_2 = q_1 \cdot 1 + q_2 \cdot 1 + q_3 \cdot 1$ (2)

$q_3 = q_2 \cdot 0$ (3)

from eqn (3) Put the value of (q_3) in eqn (2).

$q_2 = q_1 \cdot 1 + q_2 \cdot 1 + q_2 \cdot 0 \cdot 1$

$$\underbrace{q_2}_{R} = \underbrace{q_1 \cdot 1}_{Q} + \underbrace{q_2}_{R}\underbrace{(1+01)}_{P}$$

$q_2 = q_1 \cdot 1 \cdot (1+01)^*$ — (4)

Put the value of q_2 from eqn (4) to eqn (3)

$q_3 = q_2 \cdot 0$ — (3)

$q_3 = q_1 \cdot 1 \cdot (1+01)^* \cdot 0$

Put value of q_3 in eqn (1)

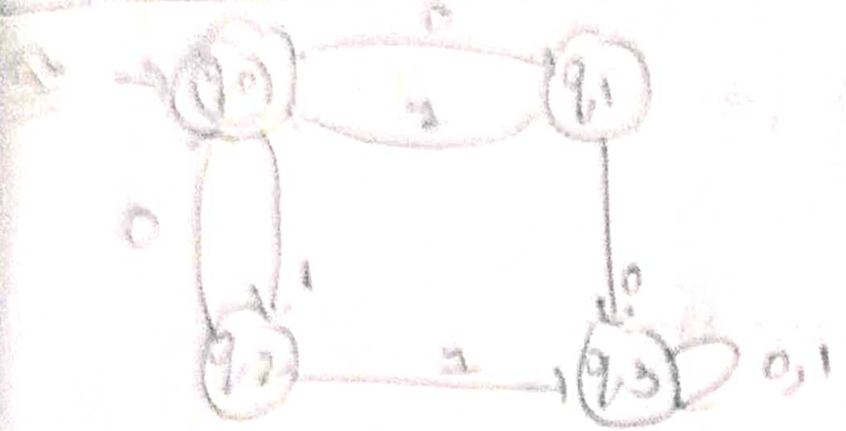
$q_1 = \wedge + q_1 \cdot 0 + q_1 \cdot 1 \cdot (1+01)^* \cdot 0 \cdot 0$

$$\underbrace{q_1}_{R} = \underbrace{\wedge}_{Q} + \underbrace{q_1}_{R} \underbrace{[0 + 1 (1+01)^* \cdot 00]}_{P}$$

$q_1 = \wedge [0+1(1+01)^* \cdot 00]^*$

$q_1 = [0+1(1+01)^* \cdot 00]^*$

Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics



Find the Regular Expression for the given diagram

$$q_0 = \Lambda + q_1 \cdot 1 + q_2 \cdot 0$$

$$q_1 = q_0 \cdot 0$$

$$q_2 = q_0 \cdot 1$$

$$q_3 = q_1 \cdot 0 + q_2 \cdot 1 + q_3 \cdot 0 + q_3 \cdot 1$$

$$q_0 = \Lambda + q_0 \cdot 0 \cdot 1 + q_0 \cdot 1 \cdot 0$$

$$\underbrace{q_0}_{R} = \underbrace{\Lambda}_{Q} + \underbrace{q_0}_{R}\underbrace{(01+10)}_{P}$$

$$q_0 = \Lambda(01+10)^*$$

Main Ideas, Questions & Summary:

Library / Website Ref.:-

Mealy & Moore Machines

Limitation of FA → o/p →

① FA ⟶ with o/p → ways

② Final state ×
↳ String Acceptability'

The finite automata in which output is associated with each state. Every state of these finite Machine has a fixed output

$Mo = (Q, \Sigma, \delta, I.S, \Delta, \lambda')$

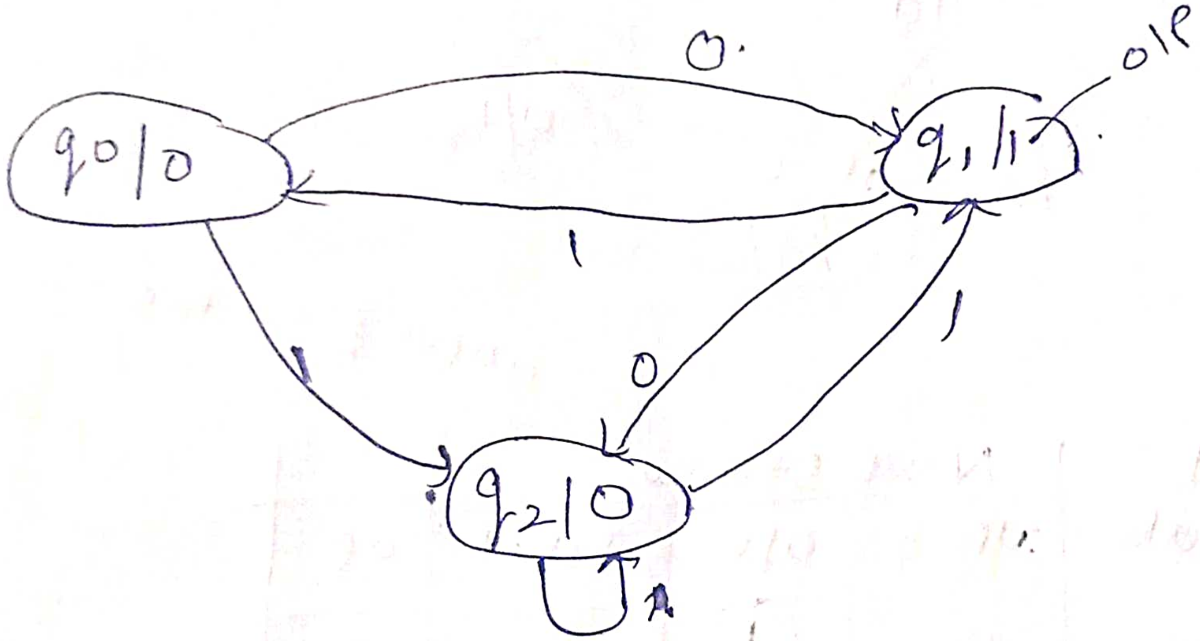
Q → Set of states
Σ → Set of inputs
δ → Transition function
I.S → Initial state.
Δ → output symbols
λ' ⇒ output function

These are the tupples of the Moore Machine.

$Me = (Q, \Sigma, \delta, I.S, \Delta, \lambda)$

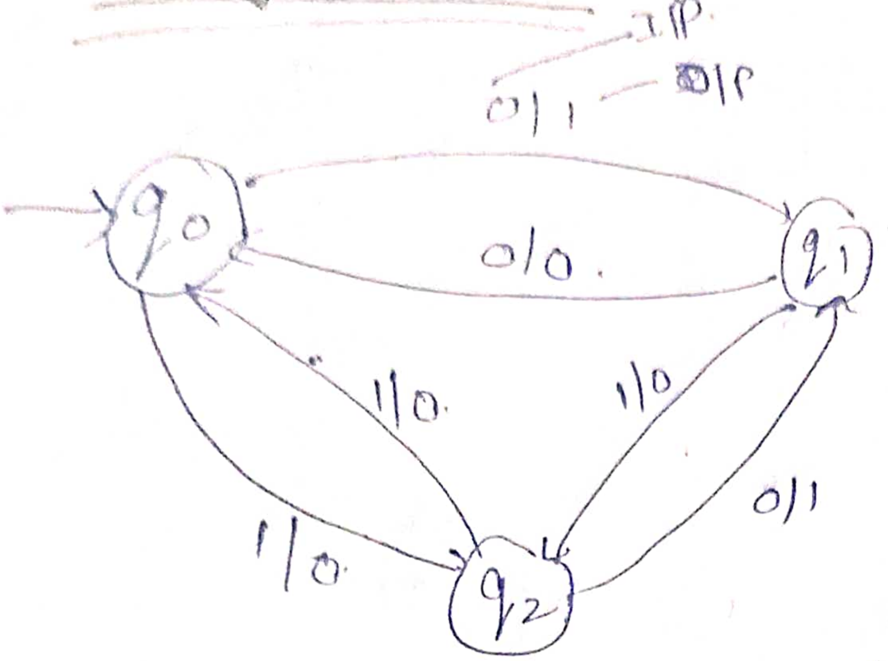
Moore = $\lambda' : Q \to \Delta$ ✓
Mealy = $\lambda = Q \times \Sigma \to \Delta$ ✓

Moore Machine



Present State	Next State		output
	I/P=0	I/P=1	
→q0	q1	q2	0
q1	q2	q0	1
q2	q2	q1	0

Mealy Machine



output of Next state

Present state	Next state I/P=0	O/P	I/P=1	OP
→ q0	q1	1	q2	0
q1	q0	0	q2	0
q2	q1	1	q0	0

Conversion to Moore to Mealy Machine

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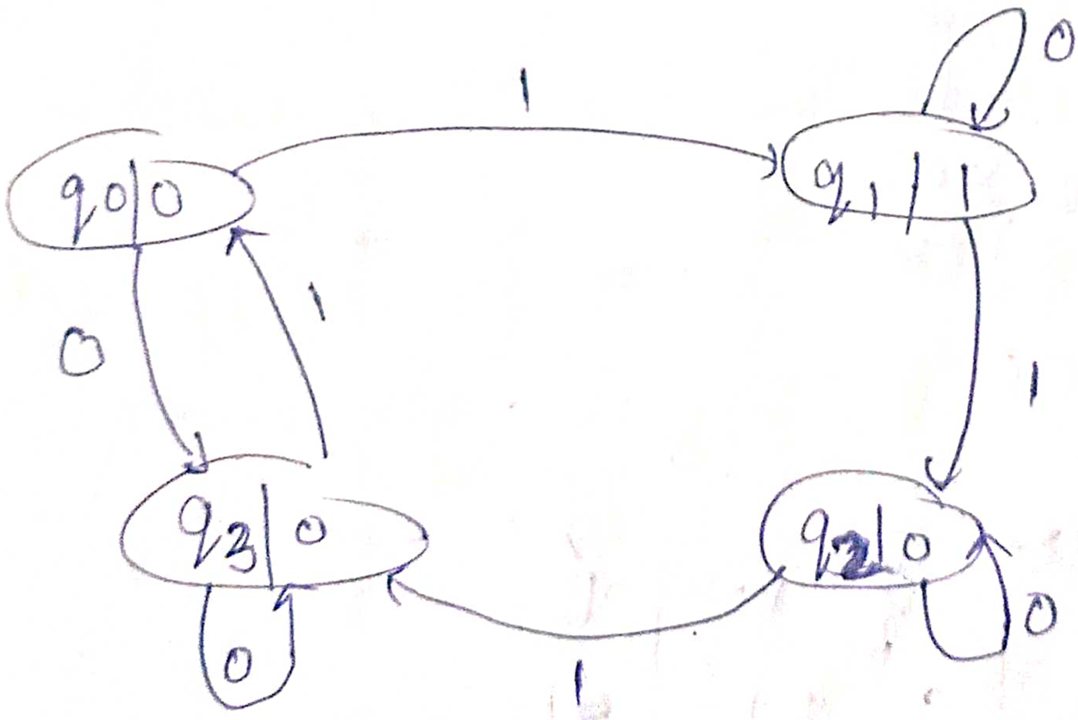
Date	Unit No	Lecture No	Faculty	Subject Name	Subject Code	Main Topics:-

P.S	Next state		O/P
	i/p=0	i/p=1	
→q0	q3	q1	0
q1	q1	q2	1
q2	q2	q3	0
q3	q3	q0	0

① STT ⟶ STD
STD ⟶ STT



Main Ideas, Questions & Summary:

Library / Website Ref.:-

(2) Tupples → define

$M_o = (Q, \Sigma, \delta, \Delta, \lambda, q_0)$

$M_o = (\{q_0, q_1, q_2, q_3\}, \{0,1\}, \delta, q_0, \Delta, \lambda)$

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

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

Initial $= \{q_0\}$

$\Delta = \{0,1\}$

$\lambda'(q_0) = 0$

$\lambda'(q_1) = 1$

$\lambda'(q_2) = 0$

$\lambda'(q_3) = 0$

(3) Find out the outputs

$\lambda'(q_0) = 0$

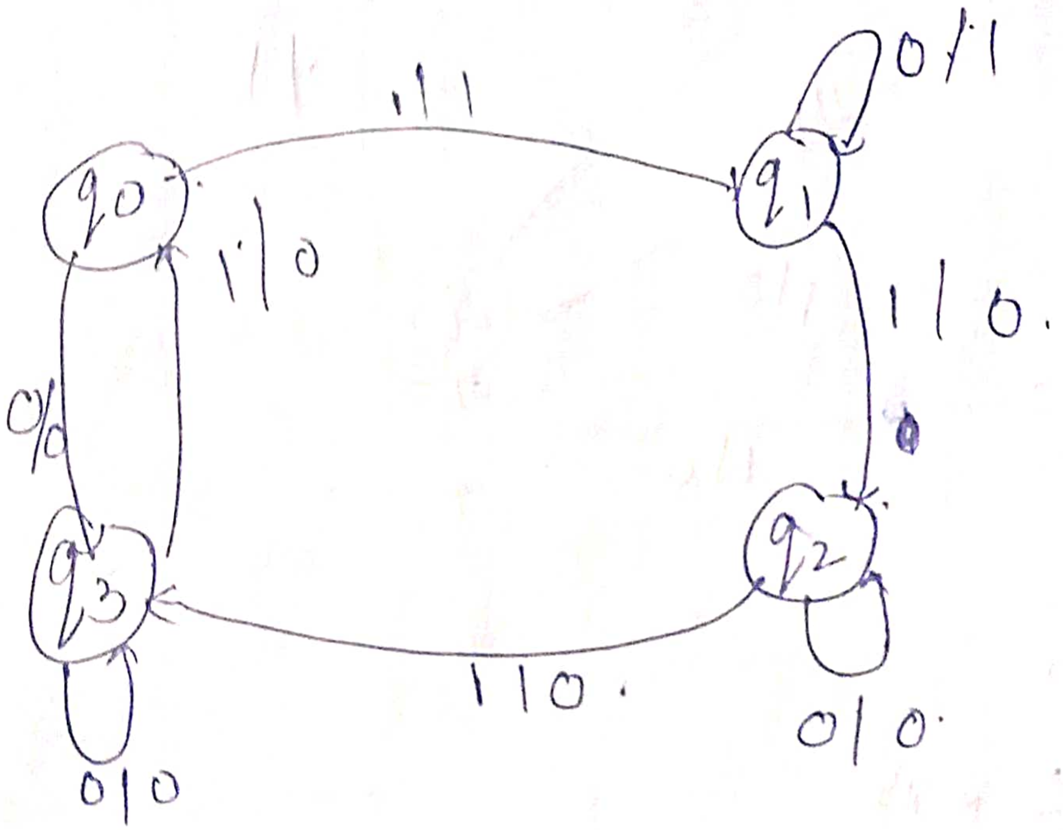
$\lambda'(q_1) = 1$

$\lambda'(q_2) = 0$

$\lambda'(q_3) = 0$

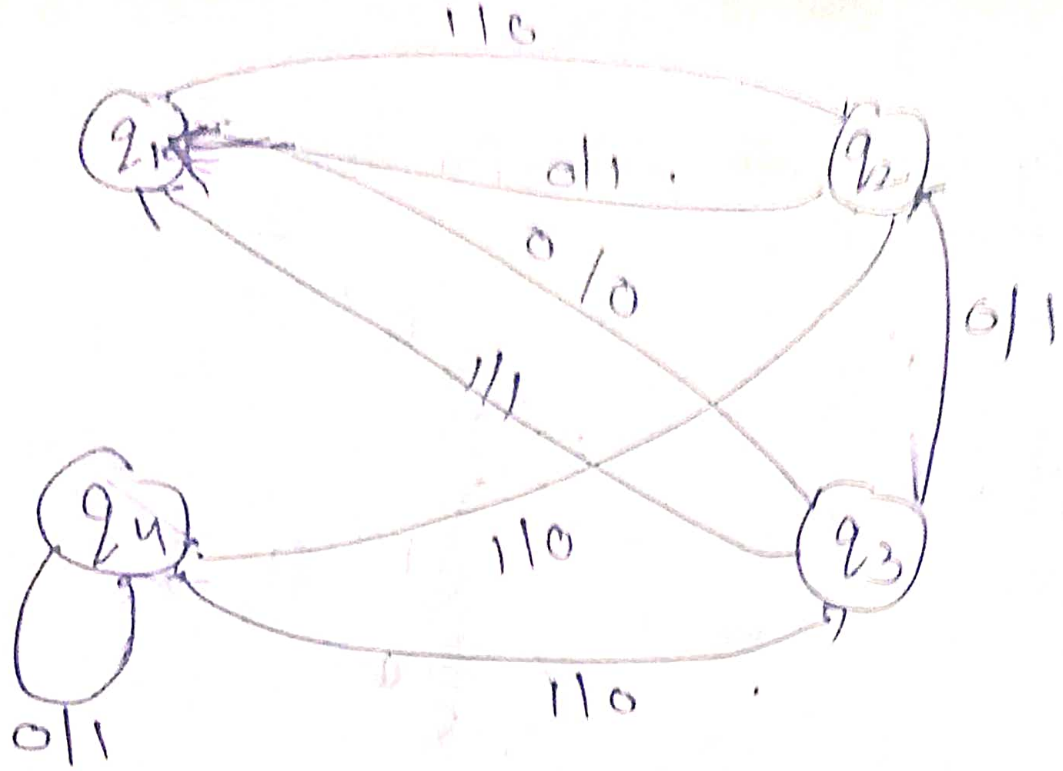
(4) Mealy M/C

P.S	Next State			
	I/P=0	OP	I/P=1	OP
→q_0	q_3	0	q_1	1
q_1	q_1	1	q_2	0
q_2	q_2	0	q_3	0
q_3	q_3	0	q_0	0



Conversion of Mealy to Moor M/C

P.S	Next State			
	q=0	o/p	q=1	o/p
→q1	q3	0	q2	0
q2	q1	1	q4	0
q3	q2	1	q1	1
q4	q4	1	q3	0



② Tuples

$\Delta = \{0,1\}$

$\lambda \to Q \times \Sigma \to O$

$q_1 \times 0 \to 0$

③ Find o/p

$q_1 \to 1$

$q_2 \to 0, 1$

$\to q_{20} \to 0$

$\to q_{21} \to 1$

$q_3 \to 0$

$q_{40} - 0$

$q_{41} \to 1$

P.S	Next state		O/P
	I/P=0	I/P=1	
→ q1	q3	q20	1
q20	q1	q40	0
q21	q1	q40	1
q3	q21	q1	0
q40	q41	q3	0
q41	q41	q3	1

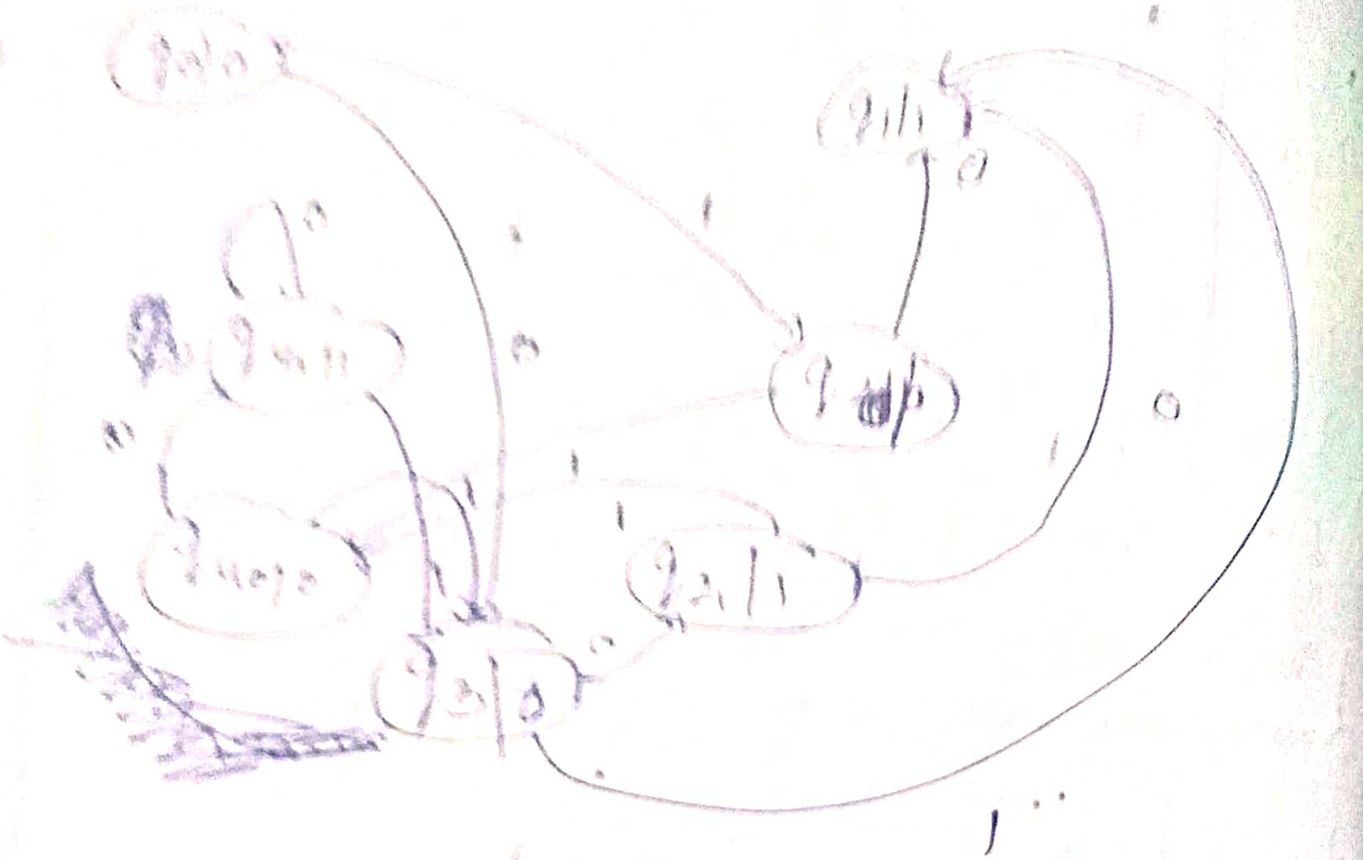
If initial state output is 1 then we have to create new start state and output is 0.

P.S	Next state		O/P
	I/P=0	I/P=1	
q0	q3	q20	0
q1	q3	q20	1
q20	q1	q40	0
q21	q1	q40	1
q3	q21	q1	0
q40	q41	q3	0
q41	q41	q3	1

Main Ideas, Questions & Summary:

Library / Website Ref.:-

If the start is associated with output 1 then add a new state whose transitions are same as that of the start state but output is zero and make the new state as the start state.



Q. Moore M/C to Mealy M/C.

P.S	Next state I/P=0	Next state I/P=1	O/P
→ q1	q1	q2	0
q2	q1	q3	0
[illegible]	q1	q3	1

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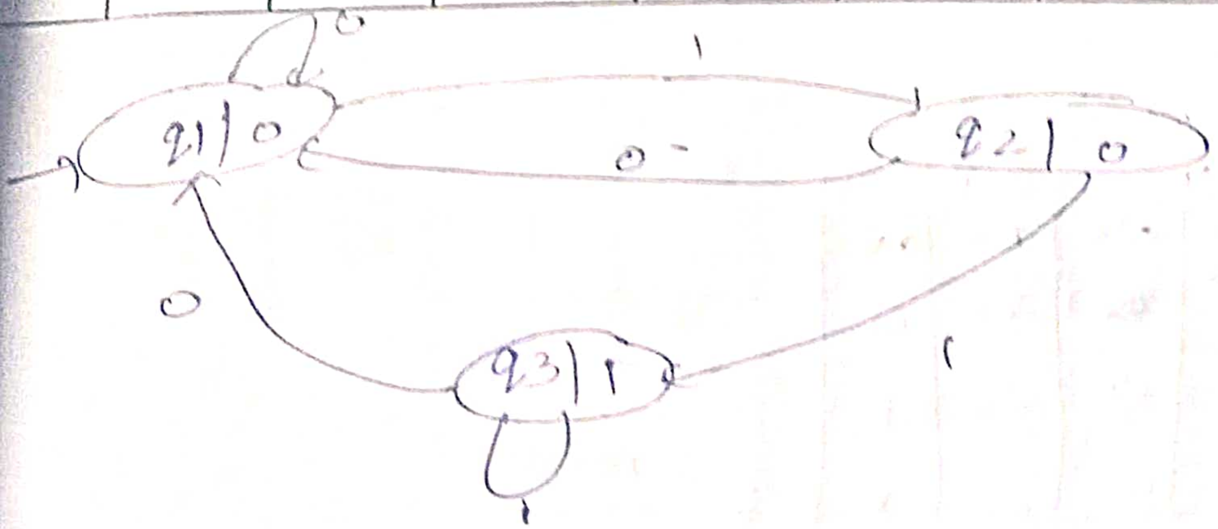
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-



② Tupple

$M_0 = (Q, \Sigma, \delta, I\cdot S, \Delta, \lambda')$

where $Q = \{q_1, q_2, q_3\}$

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

$I\,S = \{q_1\}$

$\Delta = \{0, 1\}$

$\lambda'(q_1) = 0$

$\lambda'(q_2) = 0$

$\lambda'(q_3 = 1$

Questions & Summary:

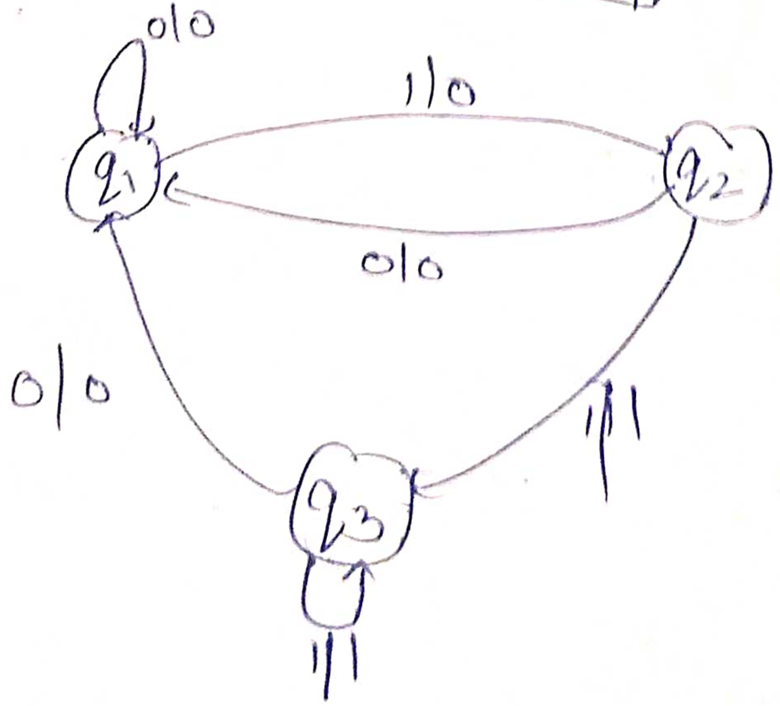
...nal:-

③ find out the output

④. Mealy M/C

P. S	Next state			
	I/P=0	O/P	I/P=1	O/P
q_1	q_1	0	q_2	0
q_2	q_1	0	q_3	1
q_3	q_1	0	q_3	1

→ Merge



If Two states are identical Merge the two states

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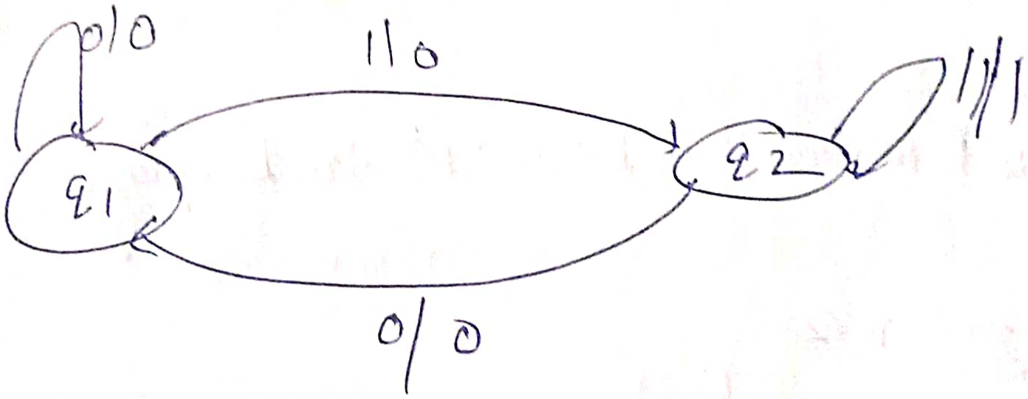
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

P.S.	N.S			
	I/P=0	O/P	I/P=1	O/P
q_1	q_1	0	q_2	0
q_2	q_1	0	q_2	1



*Imp

Pumping Lemma for RL

Prove that L → not a Regular language

Show that contradiction

(1) Assume that L is a Regular language. (RL)

(2) W is a string (language)

$|W|$ → Length of the string

Main Ideas, Questions & Summary:

Library / Website Ref.:-

step 3 $|w| \geq N$

$w = xyz \to$ break

Condition 4 its $|xy| \leq N$ & $|y| > 0$

(iv) choose m integer i

$xy^i z \notin L$

→ Hence L is not a Regular language

Note: We will not take i the value of n & I

Q. Prove that $L = \{0^n . 1^n \mid n \geq 1\}$ is not a RL.

Soln

(1) Assume that L is the Regular Language.

(2) $n=2$

$0^2 1^2$

↳ occurrence of 0 is 2

↳ occurrence of 1 is 2

$0011 \to w$

$|w| = 4$

(3) $|w| \geq n$

$4 \geq 2$

$w = xyz$

$x \to 00$	$x - 0$	$y \to 0$
$y \to 1$	$y \to 01$	$y \to 0$
$z - 1$	$z \to 1$	$z \to 11$
$\|y\| \leq 2$	$\|x\| y \leq n$	$\|xy\| \leq 2$
$\|3\| \leq 2$	$3 \leq 2$	$2 \leq 2$
X		$1 > 0$

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Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

(4) $i=2$

$xy^i z$

$0^1 0^2 11$

$\Rightarrow 0^3 1^2 \notin L$

→ It is proven that the given language is not the RL

(2) $n=3$

$0^3 1^3$

↳ occurrence of 0 is 3

↳ " " 1 " 3

000111

$|w| = 6$

(3) $|w| \geq n$

$6 \geq 3$

$w = xyz$

$x \to 0$

$y \to 0$

$z \to 0111$

$|xy| \leq 2$

$2 \leq 2$

$x \to 00$

$y \to 0$

$z \to 111$

$|xy| \leq 3$

$3 \leq 3$

Main Ideas, Questions & Summary:

Library / Website Ref.:-

(iv) choose integer

$i = 3$

$x\ y^{i}\ z$

$00\ (0)^{3}\ 111$

$00\ 000\ 111$

$0^{5}\ 1^{3} \notin L$

→ Therefore it's not a RL

Regular Grammar

↳ To understand any type of Grammar we should Understand

Production Rules :-

Representation of Grammar

$$G = \{N, T, P, S\}$$

or

$$G = \{V_N, \Sigma, P, S\}$$

$N/V_N \Rightarrow$ Set of Variables / Non-Terminals $\{A, B ---- Z\}$

$T \rightarrow$ Set of Terminals

$\Sigma = \{a --- z, \{0 --- 9\}$

$P \rightarrow$ Production Rules.

$S \rightarrow$ Start Symbol → must be the Non-Termi

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Date	Unit No	Lecture No	Faculty	Subject Name	Subject Code	Main Topics
				Regular Grammar		

Construction of Finite Automata from RG

Conversion of RG from FA

RG → FA -   G = (V_N , Σ , P, S)

V_N → A_0, A_1 .... = q_0 q_1

states

Σ → a, b

S → Corresponds to system

Production Rules (P) -

1. $A_i \to a$] → Transition Terminated unique final state is created

2.1. $A_i \to aA_j$] → $q_i \longrightarrow q_j \Rightarrow a \mid q_i \xrightarrow{a} q_f$

2.2. $A_i \to a$

Main Ideas, Questions & Summary:

Library / Website Ref.: