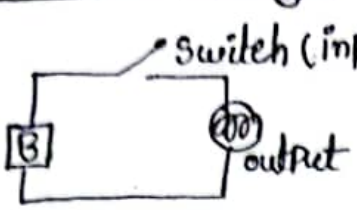
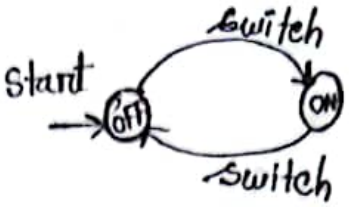
[THEORY OF COMPUTATION]

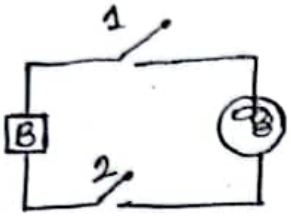
⊖ Automata Theory:

tract
putational
vice

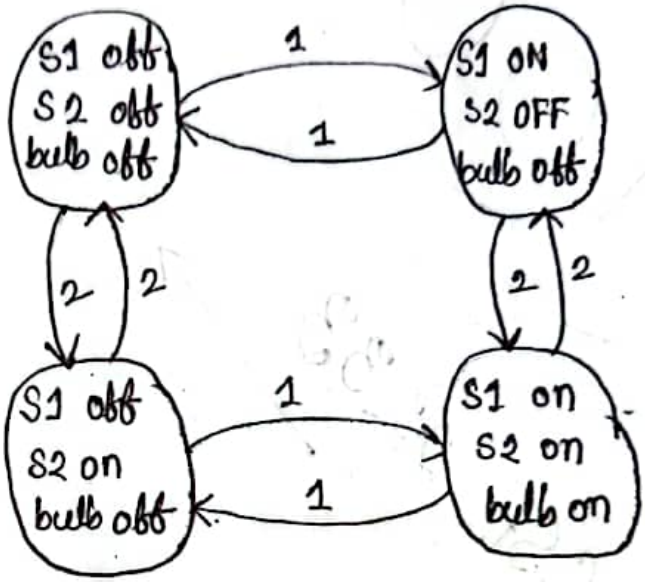




1 ft input
A(0,1)



2 ft input
(00, 01, 10, 11)



* Finite automata:

(finite amount of memory)

⇒ DFA (Deterministic Finite Automata)

⇒ NFA (Non-Deterministic Finite Automata)

the ability of a device to make arbitary choices.

= Problems will have yes/no as an answer.

* lexical analyzer is to recognize expressions/variable in programming languages.

= Alphabet [A finite set of symbols]

$\Sigma = \{ \ldots \}$ set symbol given for all possible combinations.

= The finite sequence of the symbols in alphabet (Σ) is a string (w)

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(*) Σ^K = set of strings of length K.

Σ^* = set of all possible strings over alphabet Σ. (Kleene star)

Σ^+ = set of all possible strings over alphabet Σ of length ≥ 1

$\Sigma^0 = \{\varepsilon\}$ [epsilon] String of length 0.

(*) $\Sigma = \{0, 1\}$; ⇒ alphabet that contains only 0 & 1.

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

$\Sigma^2 = \{00, 01, 10, 11\}$

$\Sigma^3 = \{000, 001, 010, 011, - - -\}$ → set of strings using the alphabets and the (Power) determines the length of the strings. বয় bit যের হবে।

(*) $\Sigma^+ = \Sigma^1 \cup \Sigma^2 \cup \Sigma^3 \cup - - -$

$\Sigma^* = \Sigma^0 \cup \Sigma^1 \cup \Sigma^2 \cup - - - -$

$\therefore \boxed{\Sigma^* = \Sigma^+ \cup \{\varepsilon\}}$

(*) $x = 01101$, $y = 110$

$\therefore xy = 01101110$

$yx = 11001101$

(*) Language: meaning full strings [নির্দিষ্ট কোন ভাষা বুঝাবে]

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

$\boxed{w\#w}$ ⇒ [String format] কোন ধরণের ভাষা আসবে।

Language: $0\#0$, $1\#1$, $00\#00$, $00\#11$ X

$\boxed{w\#w^R}$ (w^R = reverse)

$01\#10$

$110\#011$

* ϕ = empty language

* $\phi \neq \{\varepsilon\}$

DFA ⇒ Deterministic Finite Automata

↳ recognize language, one step at a time.

⇒ States, $Q = \{q_1, q_2, q_3 ---\}$

⇒ alphabets, $\Sigma = \{0, 1, --\}$

⇒ start state = $q_1 \rightarrow$ ○ [arrow sign দিয়ে start বুঝায়]

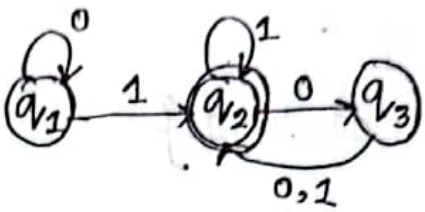
⇒ Final / Accept state = $\{q_2\} \rightarrow$ ◎

⇒ Transition function:

State \ Input	0	1
→ q_1	q_1	q_2
* q_2	q_3	q_2
q_3	q_2	q_2

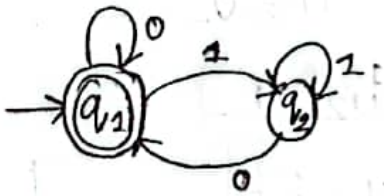
Start state

Final state



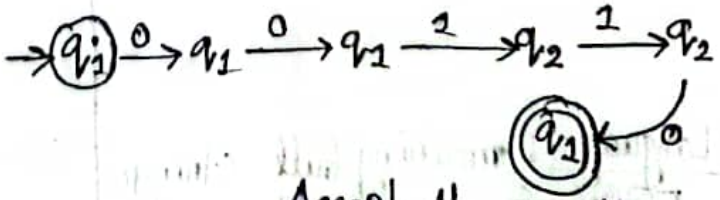
* example :

1. States, $Q = \{q_1, q_2\}$
2. Starting state = q_1
3. Final state = $\{q_1\}$
4. Accepted inputs / alphabets = $\{0, 1\}$
5. Transition Function:



State \ input	0	1
* → q_1	q_1	q_2
q_2	q_1	q_2

input = 00110



Accept the input.

6. language :

Set of all strings that ends with 0. [Accepted strings]

{এইভাষাসেহু, input string এর শেষে (0) থাকলেই final state এ যাওয়া যায়।}

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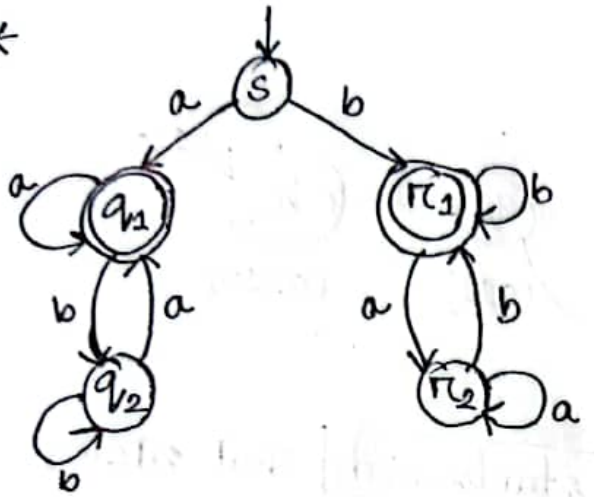
⊖ Deterministic হওয়ার শর্ত:

(1) প্রতিটি state এর অবশ্যই input alphabet এর transition function থাকবে।

(2) একটি state এর কোনো 1টি input এর জন্য সর্বোচ্চ 1টি state এই transition হওয়া।

*

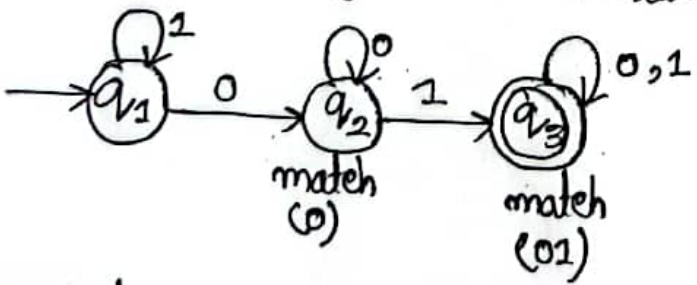


State \ Input	a	b
→ S	q_1	r_1
* q_1	q_1	q_2
q_2	q_1	q_2
* r_1	r_2	r_1
r_2	r_2	r_1

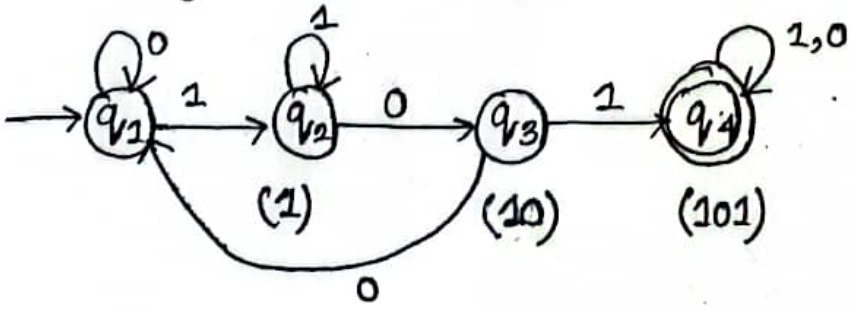
Language : Set of all strings that starts and ends with the same symbol.

⊞ Language দেয়া থাকলে draw করা:

Set of all strings that contains 01 as a substring.



101 substring



Subject :

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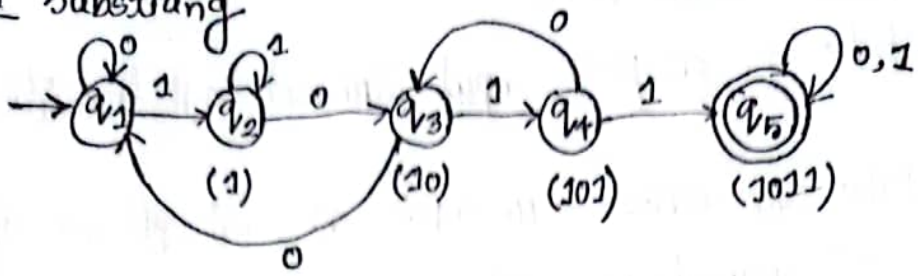
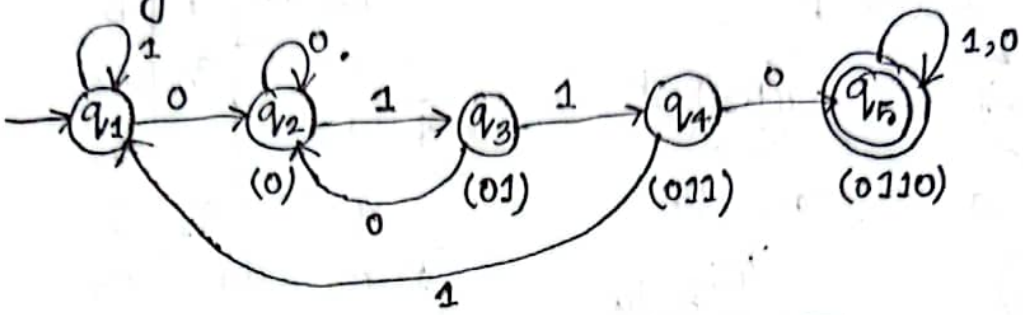
1011 substring

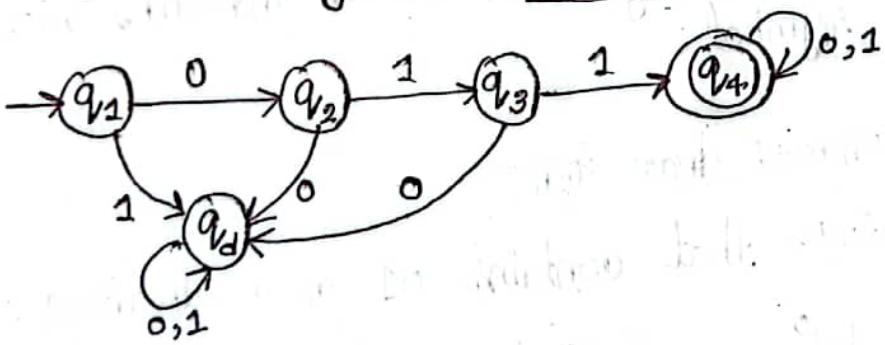


0110 substring



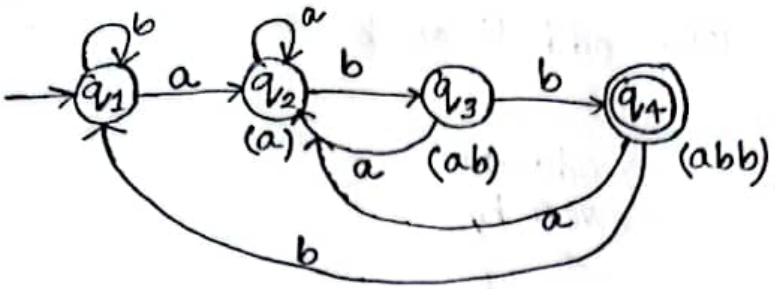
⊖ যদি contain substrings না বলে **starts with** বলা থাকে:

set of all strings that starts with 011



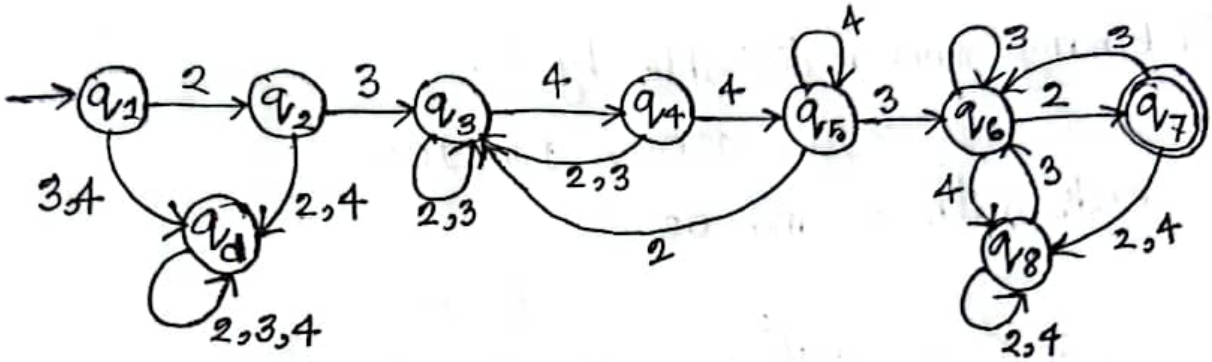
q_d = dead state

⊖ ends with abb :

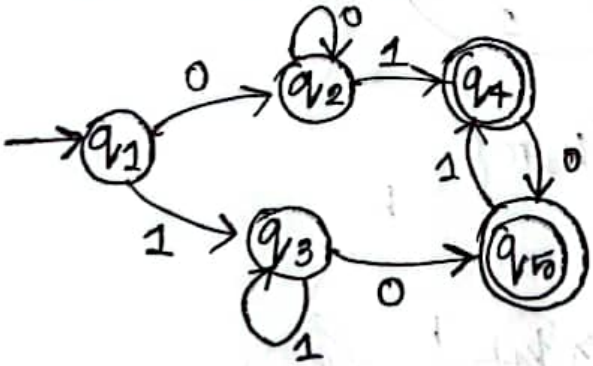


substring 1বার থাকলেই হয়।
ends with কে complete করা লাগবে।

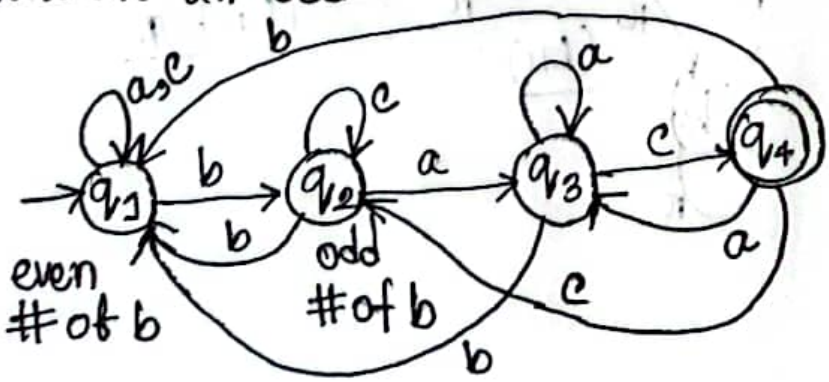
⊞ Starts with 23, contains 443 as a substring and ends with 32 ; where $\Sigma = \{2, 3, 4\}$



⊞ ends with either 01 or 10 ; $\Sigma = \{0, 1\}$



⊞ contains an odd number of b's and ends with ac.

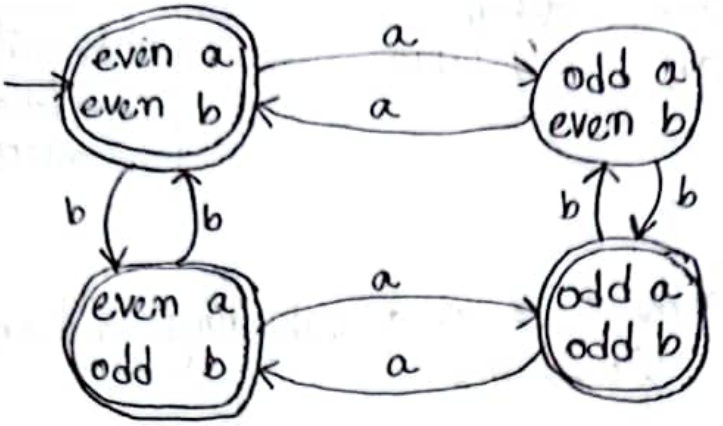


Subject :

Time :

Fall-23

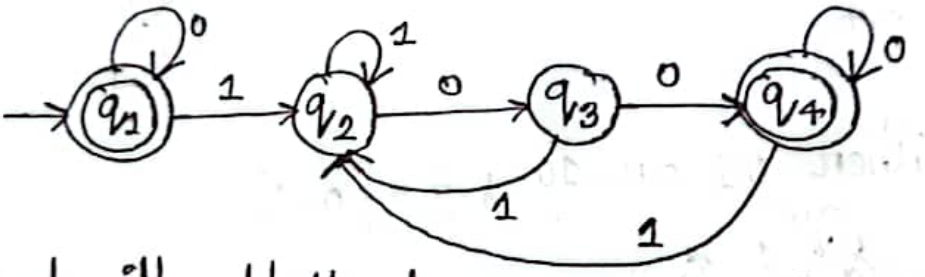
1. (a) even # of a (or) odd # of b



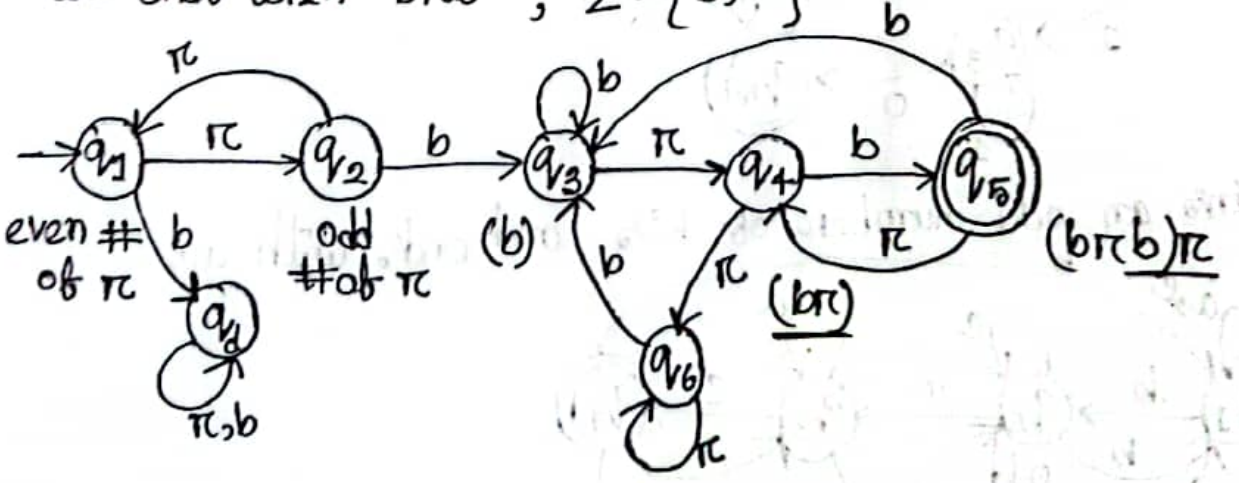
Binary numbers divisible by 4.

0, 100, 1000, 1100, 10 1100

= ends with 0 and 00.



(b) Start with odd # of π and ends with bπb ; $\Sigma = \{b, \pi\}$



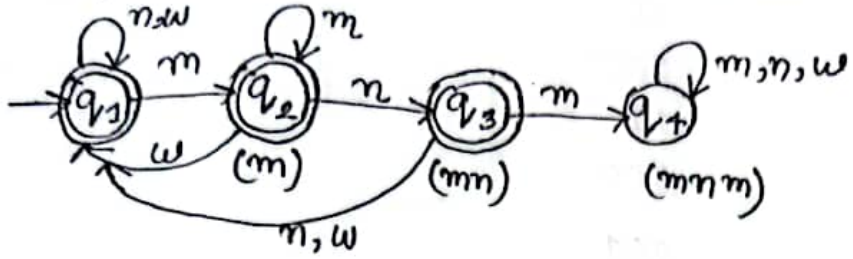
Subject :

Date :
Time :

Spring 23

1. (b) Does (not) contain mnm ; $\Sigma = \{m, n, w\}$

⇒ যেহেতু contain করানা তাই বাকিসব final state দেখা যাবে।



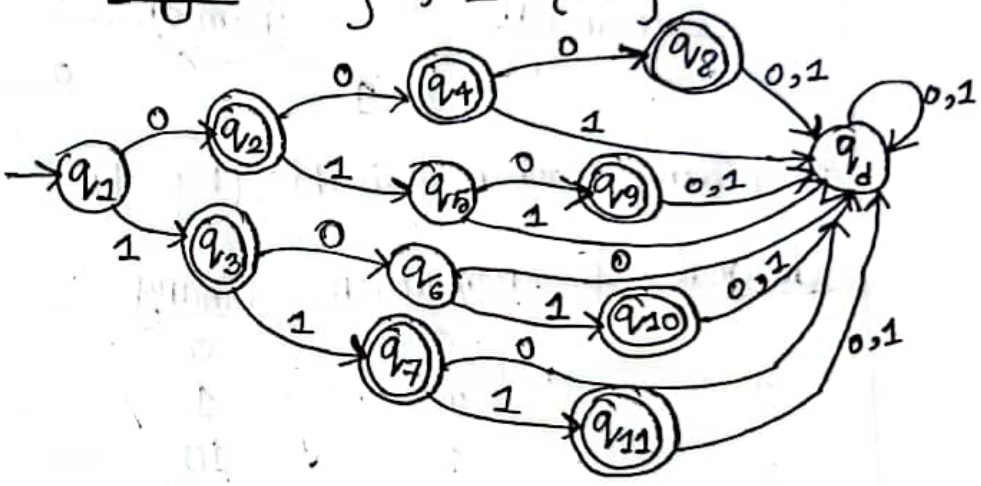
Palindrome

0, 1 — length 1

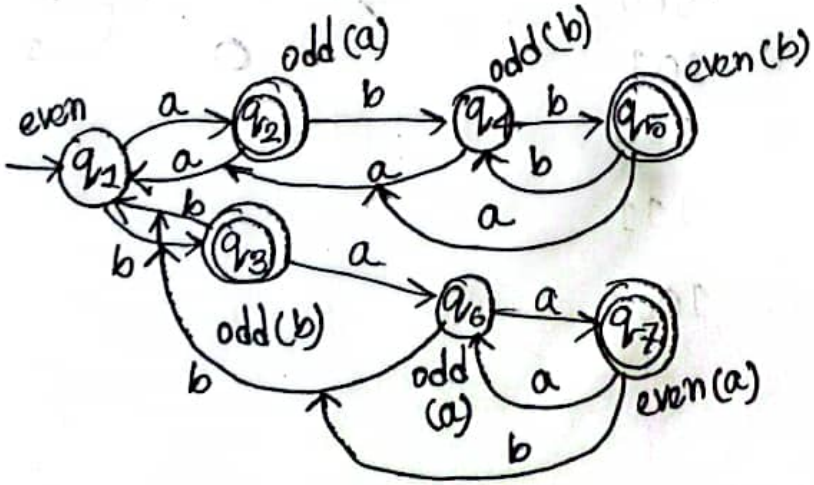
00, 11 — length 2

000, 010, 101, 111 — length 3

* $L = \{w \mid w$ is a palindrome with a max length of 3$\}$; $\Sigma = \{0, 1\}$



* $L = \{a^i b^j \mid i \geq 0, j \geq 0, i+j$ is an odd number$\}$ $\mid \Sigma = \{a, b\}$

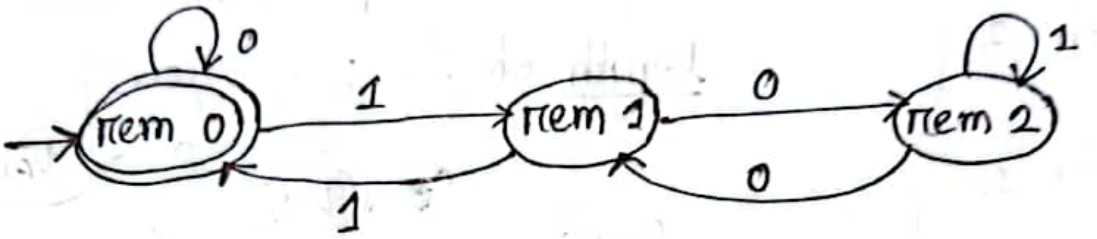


X

$a^1b^0 = a$
$a^0b^1 = b$
$a^1b^2 = abb$
$a^3b^2 = aaabb$

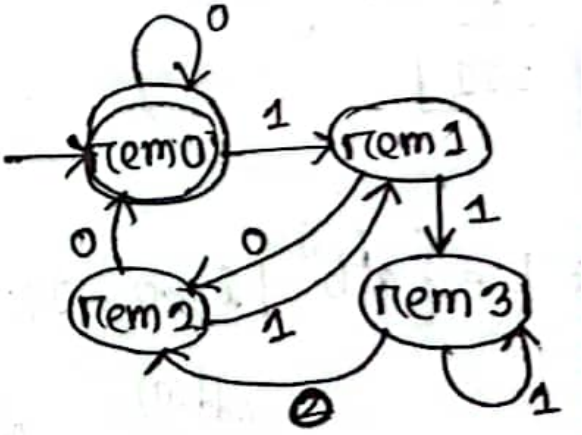
⊛ DFA : binary number divisible by 3 [2n-1 পর্যন্ত যাওয়া লাগে]

decimal	%3 remainder	binary
0	0	0
1	1	1
2	2	10
3	0	11
4	1	100
5	2	101
6	0	110



⊛ binary number divisible by 4

decimal	%4 remainder	binary
0	0	0
1	1	1
2	2	10
3	3	11
4	0	100
5	1	101
6	2	110
7	3	111
8	0	1000



⊖ Extended transition function :

$\delta(q_0, 0) = q_2$ → q_0 state থেকে [0] input এর জন্য q_2 state এ যায়।

$\delta(q_0, 1) = q_1$ [Table/box থেকে]

	0	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

} table দেওয়া থাকবে।

transition func.

(1) $\delta(q_0, 11010) = q_1$ ↓ input হিসাবে string থাকলে এটি extended transtion function.

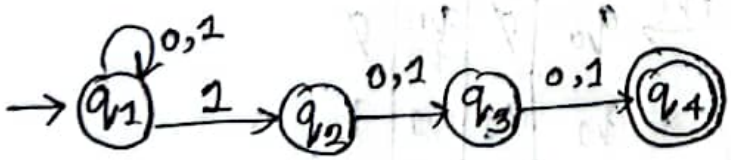
ext. trans. func.

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

⊞ NFA :

(1) Same input এর জন্য multiple state এ যাওয়া যায়।

(2) কোনো state এ transition [input এর জন্য] না থাকলেও হয়। সেক্ষেত্রে এটি empty state ϕ.



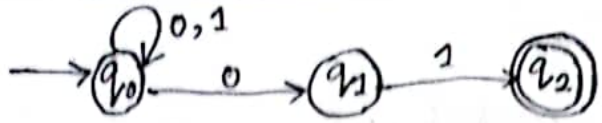
contains (1) in the 3rd position from the end.

	0	1
→ q_1	q_1	$q_1 q_2$
q_2	q_3	q_3
q_3	q_4	q_4
* q_4	ϕ	ϕ

Subject :

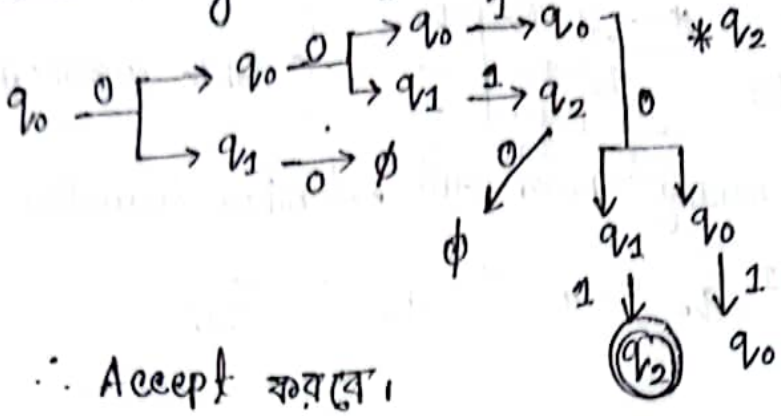
Date :
Time :

*



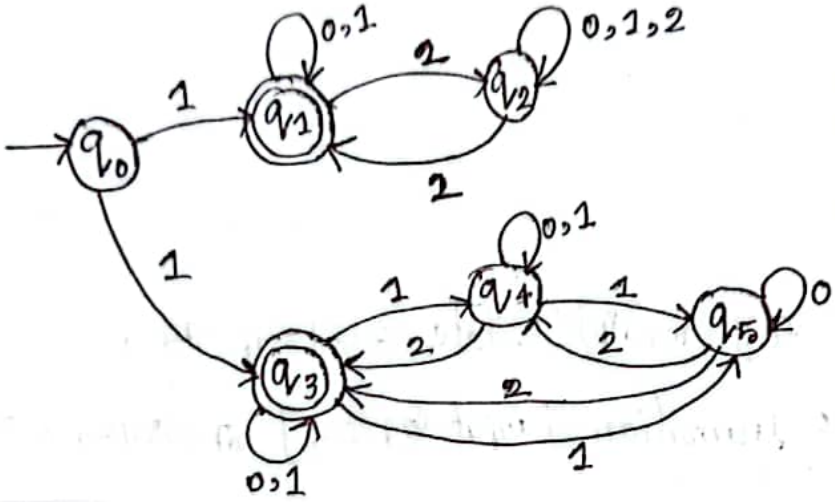
	0	1
→ q_0	q_0, q_1	q_0
q_1	ϕ	q_2
* q_2	ϕ	ϕ

00101 string এর জন্য ;



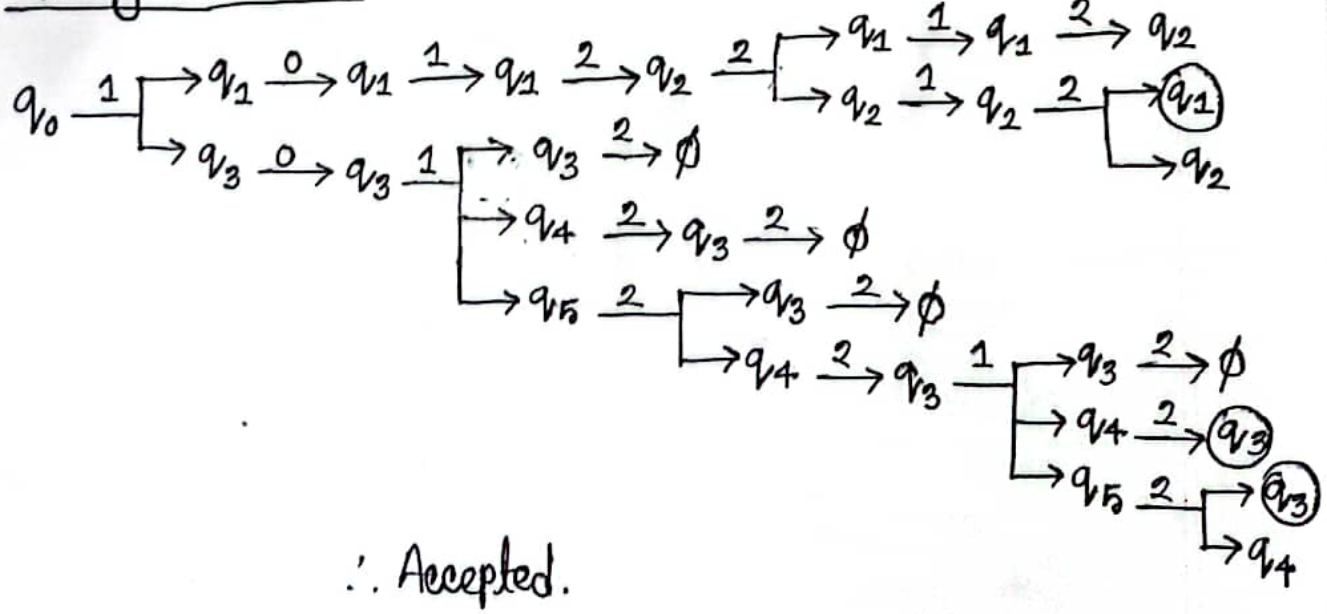
∴ Accept করবে।

*



	0	1	2
→ q_0	ϕ	q_1, q_3	ϕ
* q_1	q_1	q_1	q_2
q_2	q_2	q_2	q_1, q_2
* q_3	q_3	q_3, q_4, q_5	ϕ
q_4	q_4	q_4, q_5	q_3
q_5	q_5	ϕ	q_3, q_4

String 1012212 :



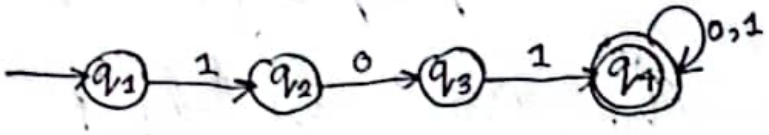
∴ Accepted.

Subject :

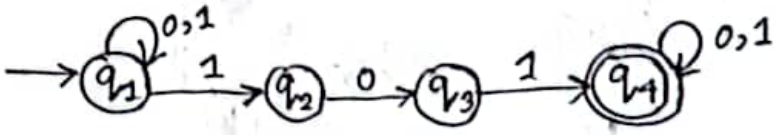
Date :
Time :

NFA designing :

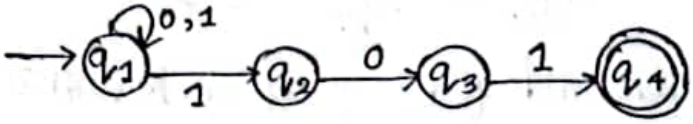
begins with 101 :



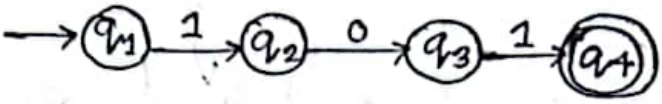
contains 101 :



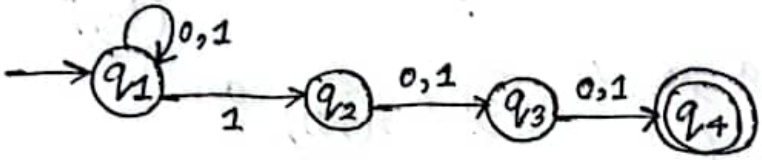
ends with 101 :



exactly 101 :



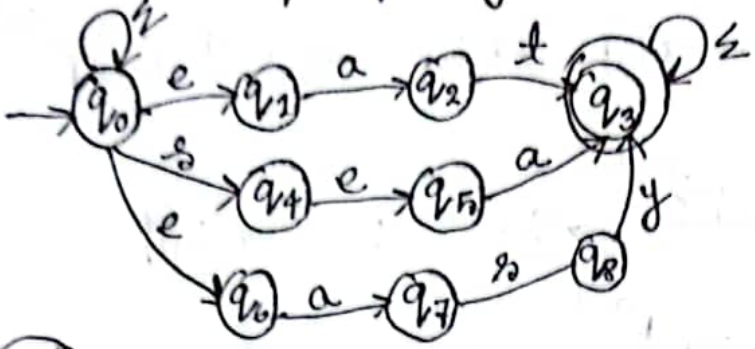
contains 1 in the 3rd position from the end :



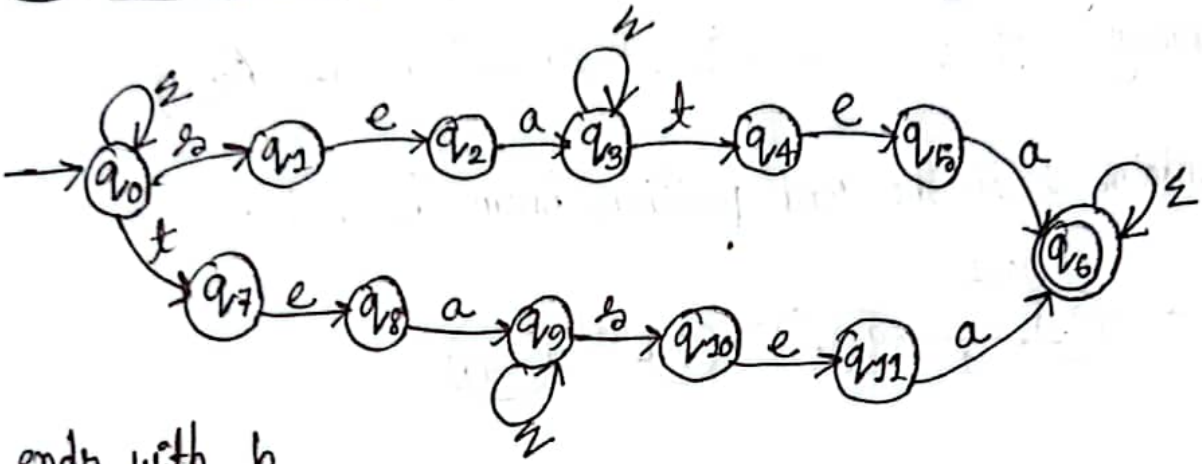
Subject : NFA

Date :
Time :

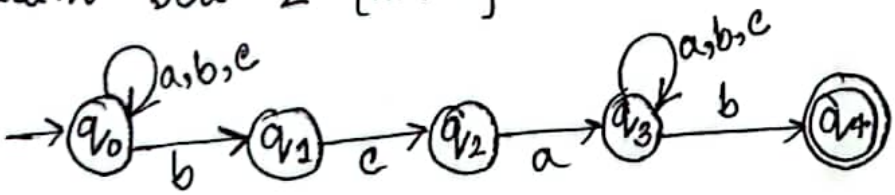
* contains eat / sea / easy : [$\Sigma = \{a, b, c, \dots, z\}$]



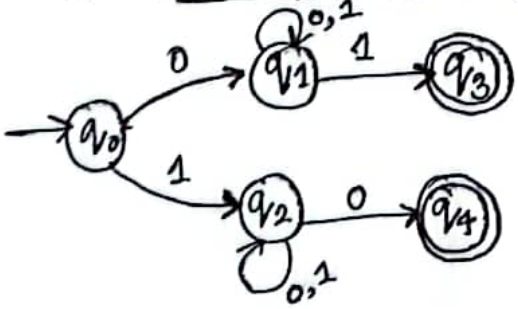
* (both) sea and tea : [যে seatea নাহয়ে teasea]



* ends with b
contains bca $\Sigma = \{a, b, c\}$



* Starts and ends with different symbols when the total length is a multiple of 2 ; $\Sigma = \{0, 1\}$.

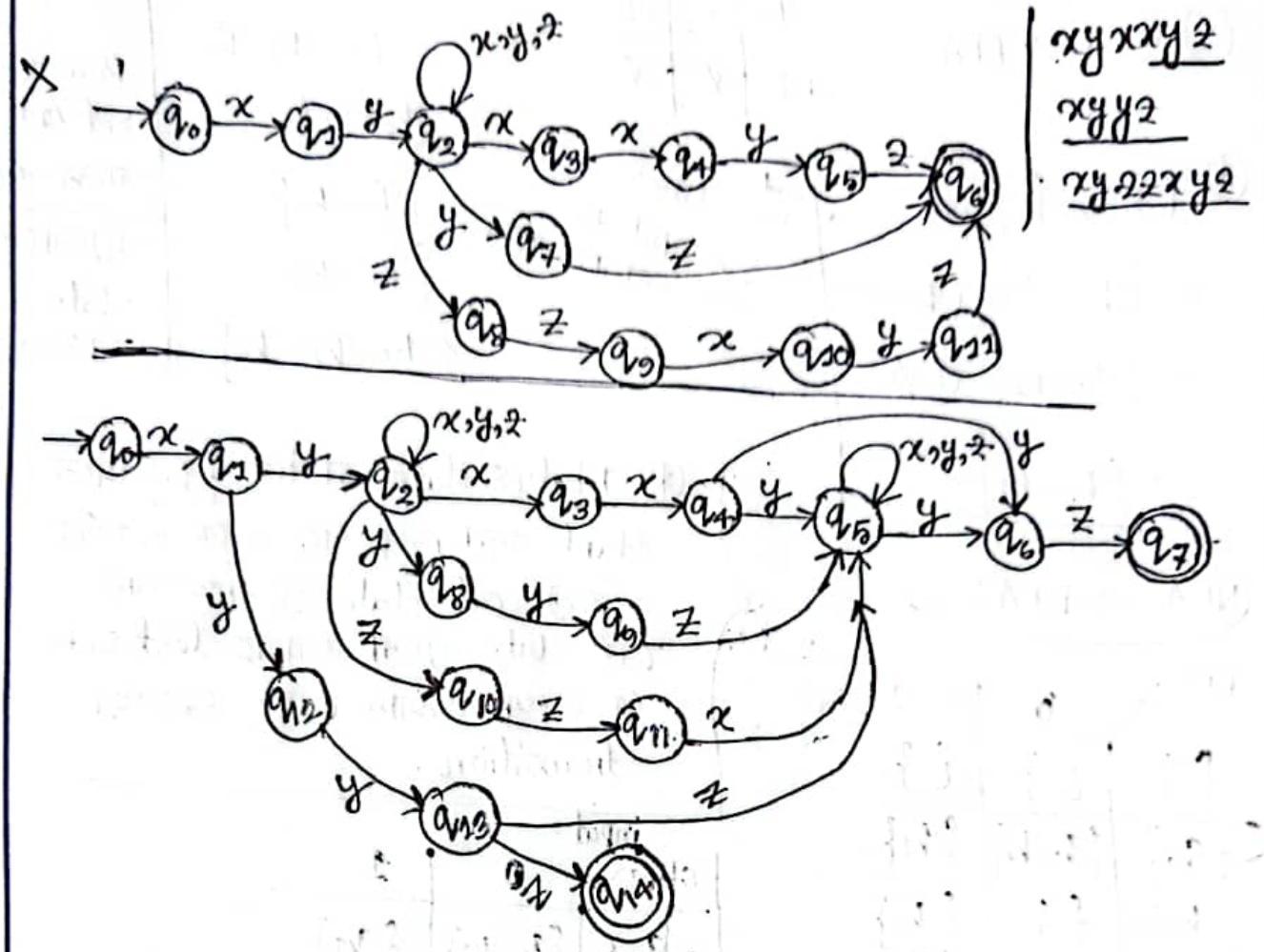


[at least ②.

Subject :

Date :
Time :

* starts with xy, contains xxy or yyz or zzx and ends with yz. $\Sigma = \{x, y, z\}$



cls-07 Subject :

Date :
Time :

conversion :

NFA → DFA

ε-NFA → NFA

(ε)-NFA → DFA

epsilon

NFA

	0	1
→ q_0	$q_0 q_1$	q_1
q_1	∅	q_2
* q_2	∅	∅

NFA state $\{q_0, q_1, q_2\}$ ← (3) → (2^3) → DFA state

$\{\}$

q_0 q_1 q_2

$\{q_0, q_1\}$

$\{q_0, q_2\}$

$\{q_1, q_2\}$

$\{q_0, q_1, q_2\}$

Power Set এর মতন করে এগুলোকে state ধরবো।

(*) $(\{q_0, q_1\}, 0)$

$= (q_0, 0) \cup (q_1, 0)$

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

$= \{q_0, q_1\}$

এই state এ (0) input এর জন্য কোথায় যাবে।

(*) total (8) state না ধরে $\{q_0\}$ দিয়ে start করা। q_0 এর থেকে 0,1 এর জন্য যেই state গুলোতে যায় সেই state গুলো আবার left side এ রেখে সেখান থেকে 0,1 এর transition.

NFA → DFA ⇒

DFA

	0	1
$\{\}$	$\{\}$	$\{\}$
→ $\{q_0\}$	$\{q_0, q_1\}$	$\{q_1\}$
$\{q_1\}$	$\{\}$	$\{q_2\}$
* $\{q_2\}$	$\{\}$	$\{\}$
$\{q_0, q_1\}$	$\{q_0, q_1\}$	$\{q_1, q_2\}$
* $\{q_0, q_2\}$	$\{q_0, q_1\}$	$\{q_1\}$
* $\{q_1, q_2\}$	$\{\}$	$\{q_2\}$
* $\{q_0, q_1, q_2\}$	$\{q_0, q_1\}$	$\{q_1, q_2\}$

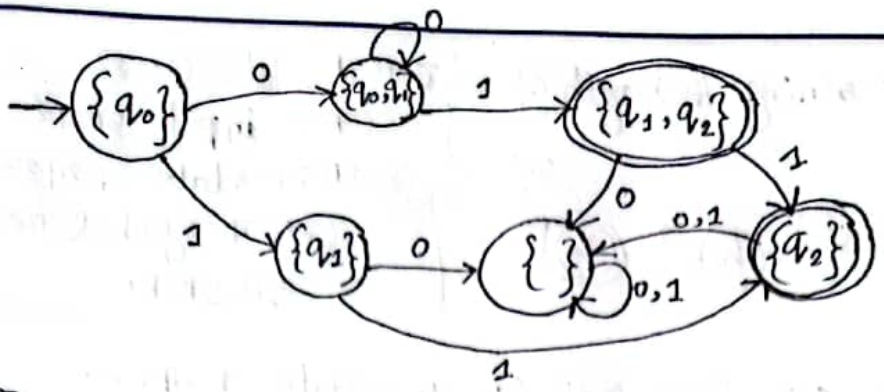
q_2 যেহেতু final state ছিলো তাই q_2 আছে এমন সব state এখানে final হবে।

state \ input	0	1
→ $\{q_0\}$	$\{q_0, q_1\}$	$\{q_1\}$
$\{q_0, q_1\}$	$\{q_0, q_1\}$	$\{q_1, q_2\}$
$\{q_1\}$	$\{\}$	$\{q_2\}$
* $\{q_1, q_2\}$	$\{\}$	$\{q_2\}$
* $\{q_2\}$	$\{\}$	$\{\}$
$\{\}$	$\{\}$	$\{\}$

⇒ Then এই table দেখে design.

Subject :

Date :
Time :

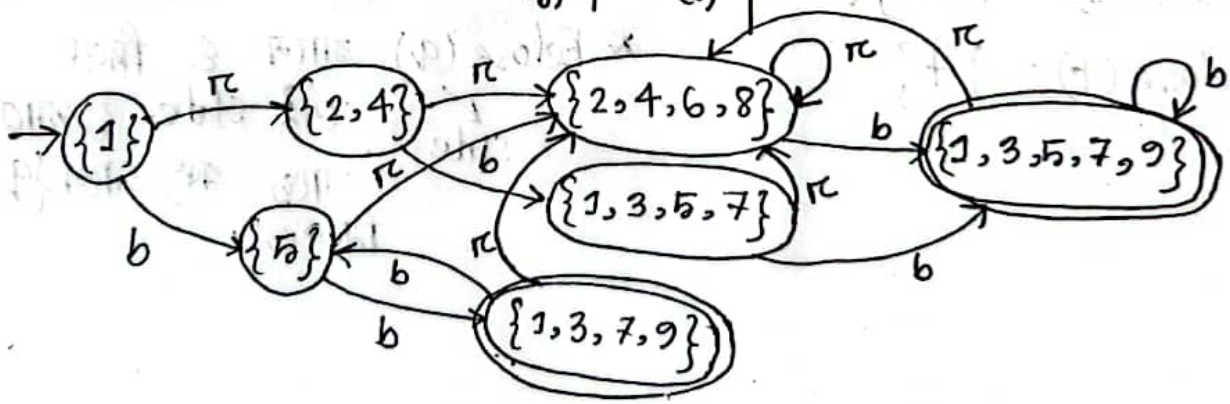


(*) NFA

	π	b
→1	2,4	5
2	4,6	1,3,5
3	2,6	5
4	2,8	1,5,7
5	2,4,6,8	1,3,7,9
6	2,8	3,5,9
7	4,8	5
8	4,6	5,7,9
*9	6,8	5

DFA	π	b
→ {1} A	{2,4} B	{5} C
{2,4} B	{2,4,6,8} [D]	{1,3,5,7} (E)
{5} C	{2,4,6,8} (D)	{1,3,7,9} (F)
{2,4,6,8} (D)	{2,4,6,8} (D)	{1,3,5,7,9} (g)
{1,3,5,7} (E)	{2,4,6,8} (D)	{1,3,5,7,9} (g)
* {1,3,7,9} (F)	{2,4,6,8} (D)	{5} (C)
* {1,3,5,7,9} (g)	{2,4,6,8} (D)	{1,3,5,7,9} (g)

* state গুলো বেশি বড় হয়েছে A, B, C, D - - - দিয়ে লাল লিখা ও রেখা নাম দিয়ে diagram.

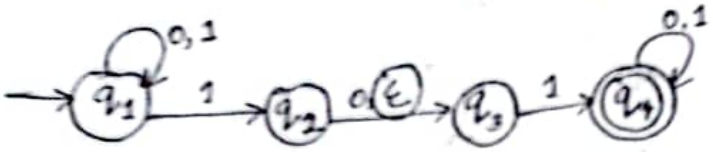


Subject :

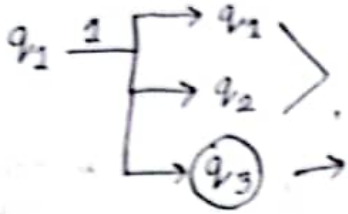
Date :

Time :

⊖ ε-NFA : [ε → string of length 0]



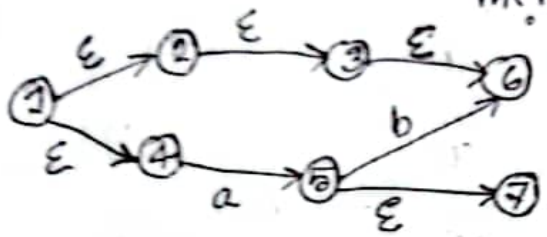
কোনো state থেকে কোনো input ছাড়াই পরের state এ যাওয়া কোনো symbol read করা ছাড়া।



1 input এর জন্য (q_1, q_2) state এ যায়।

q_1 থেকে (ε) দিয়ে q_3 তে যাওয়া যায় মানে কোনো cost নেই কোনো input খাচ্ছেনা তাই q_1 থেকে q_3 তেও যেতে পারে [1] দিয়েই অবস্থিতি।

*



Eclose (1) = {1, 2, 4, 3, 6}

Eclose (2) = {2, 3, 6}

Eclose (3) = {3, 6}

Eclose (4) = {4}

Eclose (5) = {5, 7}

Eclose (6) = {6}

Eclose (7) = {7}

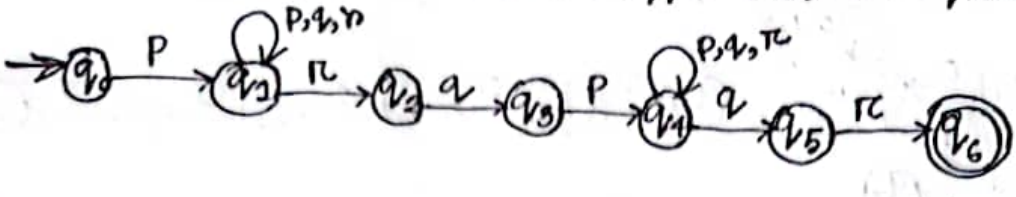
* Eclose (q) মানে ε দিয়ে যেই state গুলোতে যাচ্ছে এবং সাথে {q} টি নিজেও।

↙ state

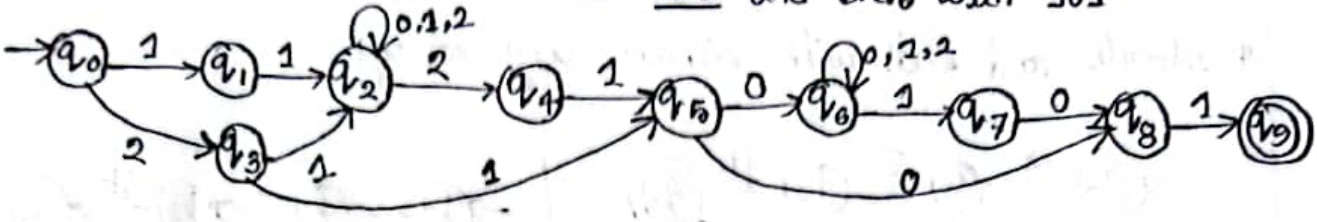
Subject :

Date :
Time :

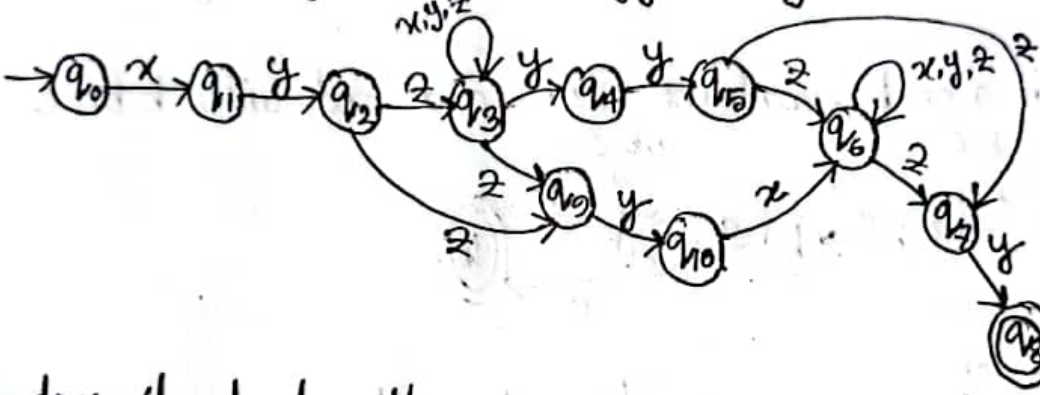
(NFA) Starts with P, contains rqp, ends with qπ.



* Starts 11 or 21 and contains 210 and ends with 101



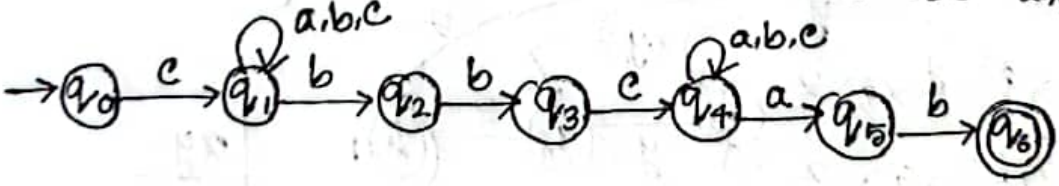
* starts with xyz, contains yyz or zyx, ends with zy.



xyz yyz zy
xyz yx zy

* doesn't start with a or b and contains bbc and ends with ab

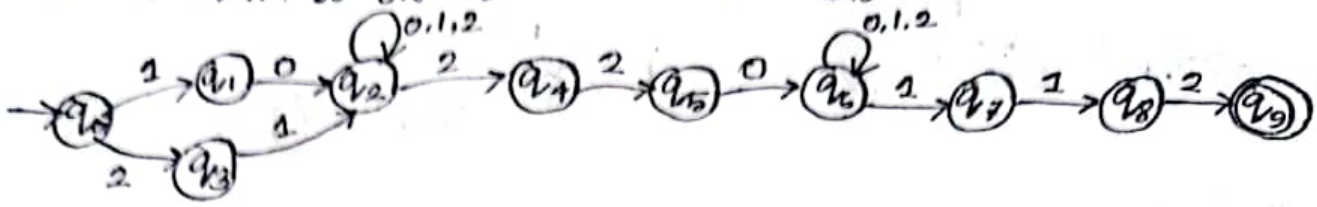
$\Sigma = \{a, b, c\}$



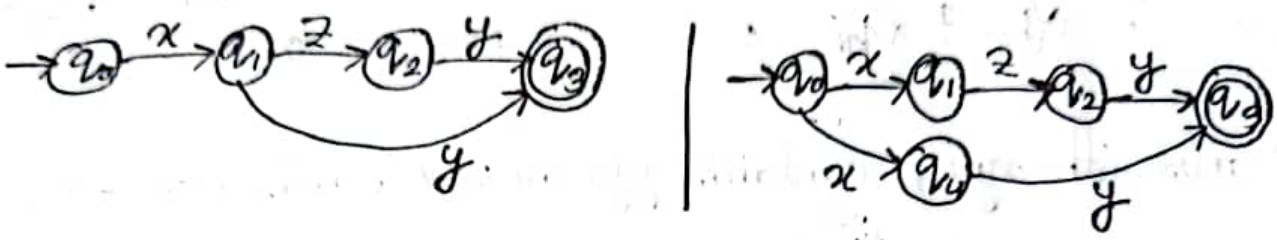
Subject :

Date :
Time :

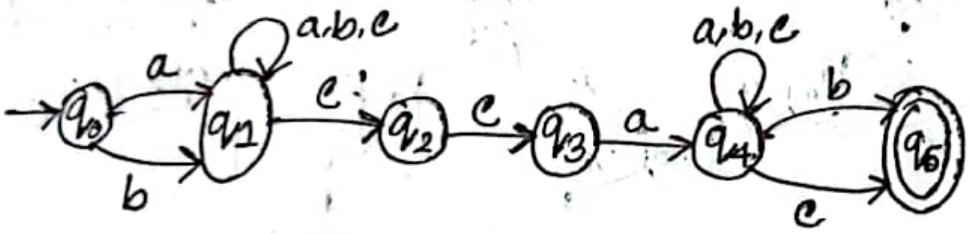
* Starts with 10 or 21 and contains 220 and ends with 112



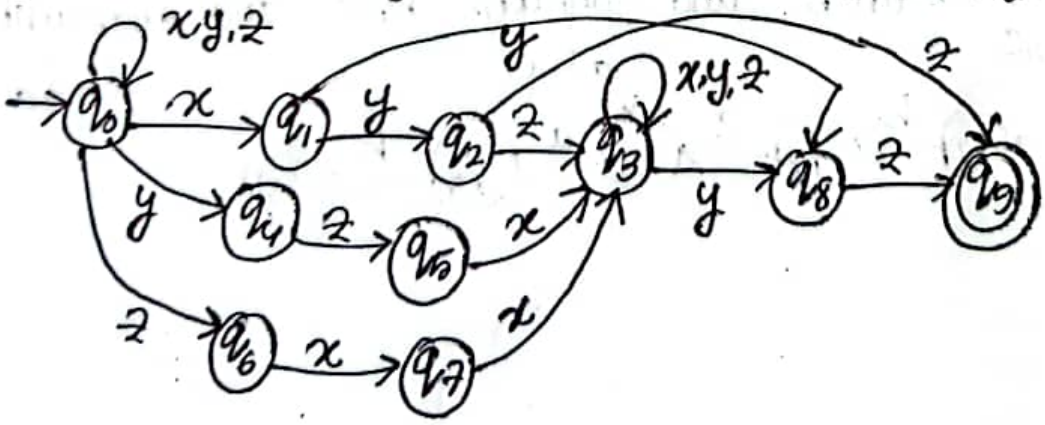
* starts and ends with either xzy or xy.



* starts with a or b, contains cca and ends with b or c.



* contains xyz or yzx or zxx and ends with yz.

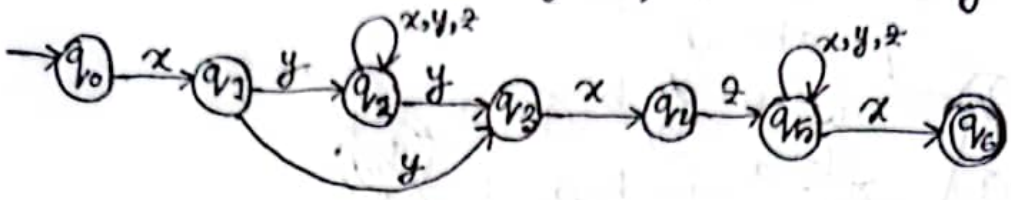


xyz

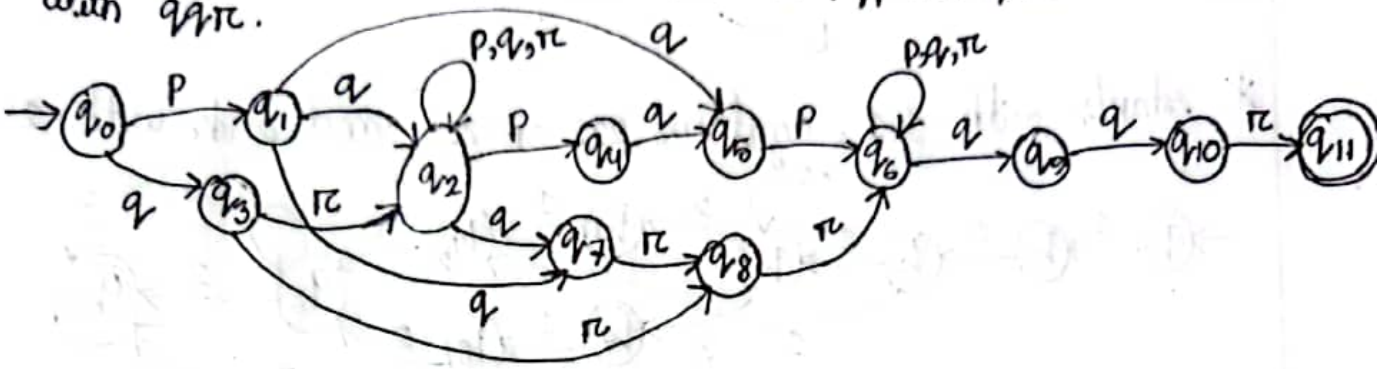
Subject :

Date :
Time :

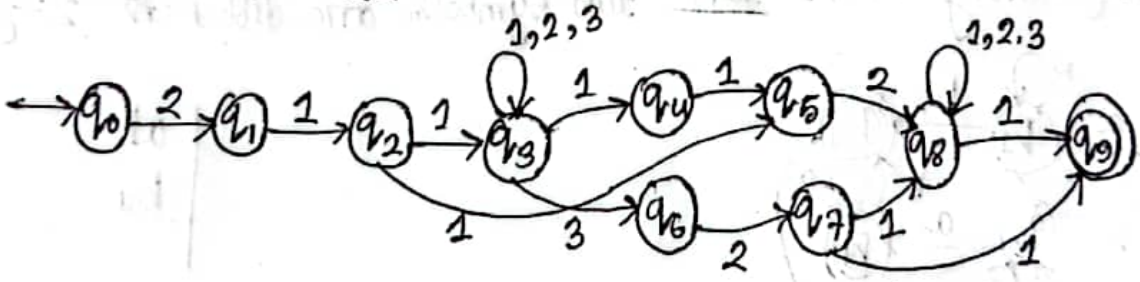
* ends with x, contains yxz, starts with xy.



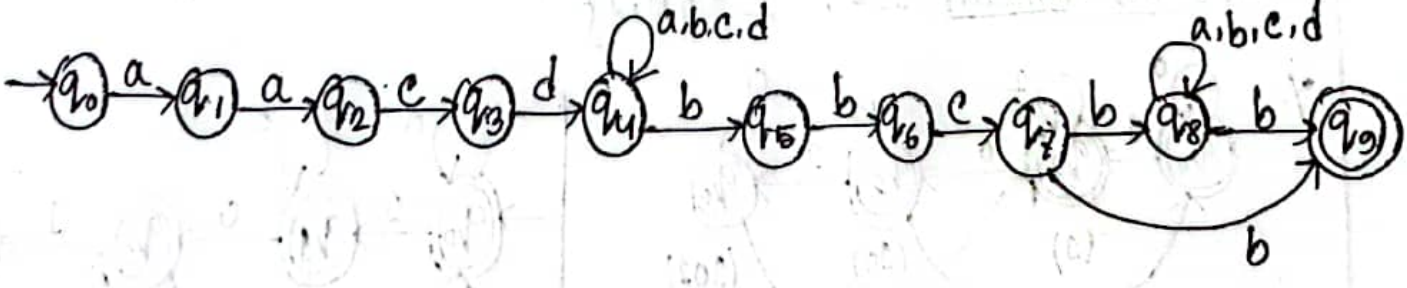
* starts with pq or πq and contains pqp or qπq and ends with qqπ.



* starts with 211 and contains 112 or 321 and ends with 1.



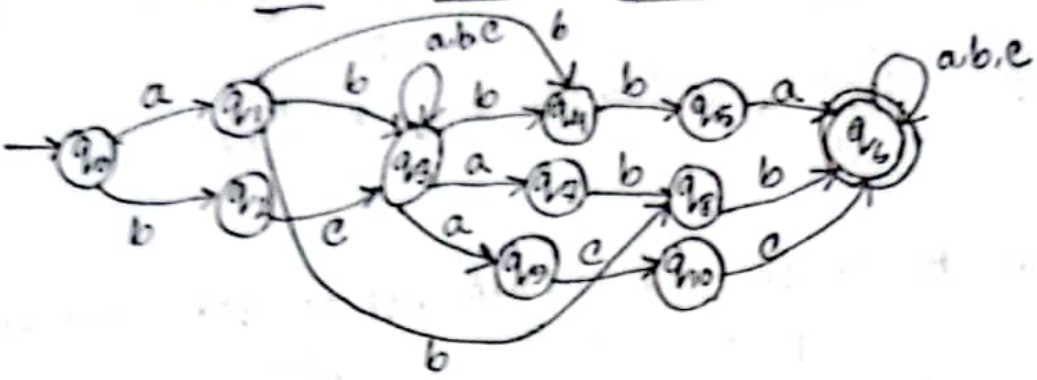
* ends with b and contains bbcb and starts with aacd.



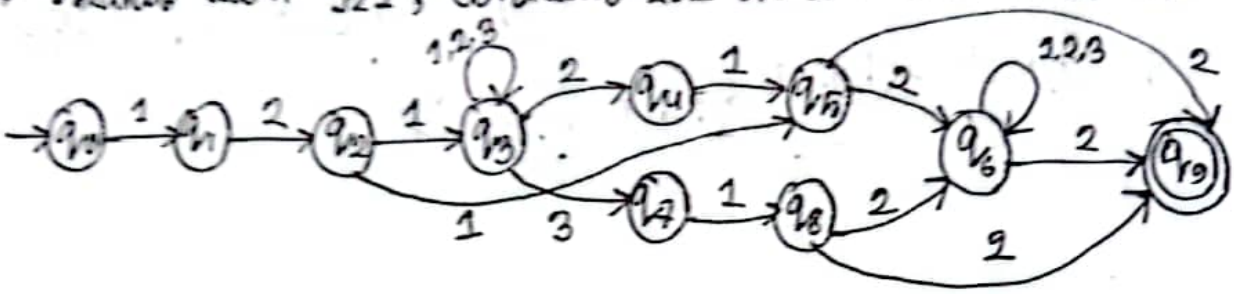
Subject :

Date :
Time :

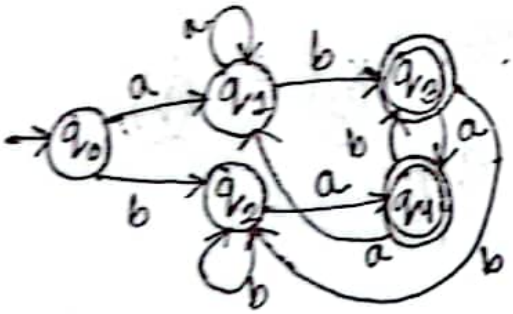
* contains bba or abb or acc and starts with ab or bc.



* starts with 121, contains 212 or 332 and ends with 2.

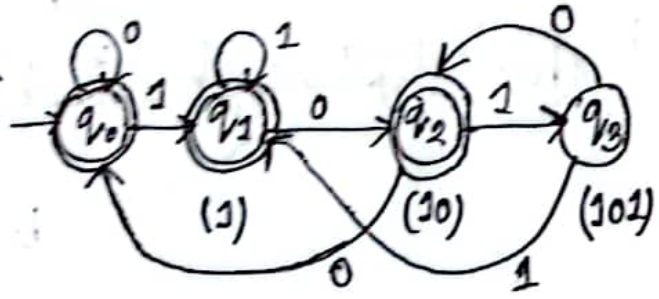


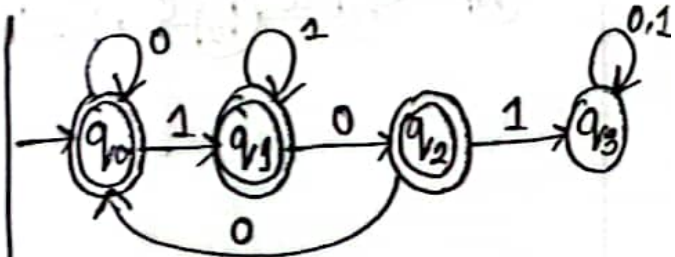
DFA any string where last two symbols are different $\Sigma = \{a, b\}$



| ab
| ba

* does not contain 101. $\Sigma = \{0, 1\}$





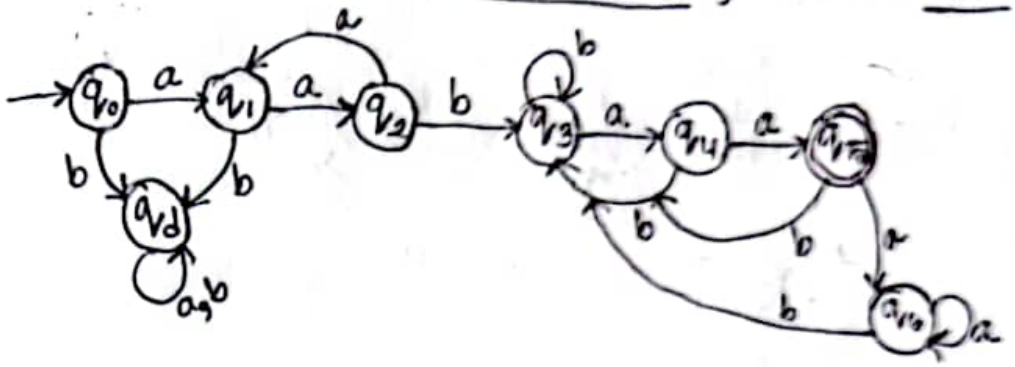
end না থাকলে last অংশটা মিলানো লাগানো।

Subject :

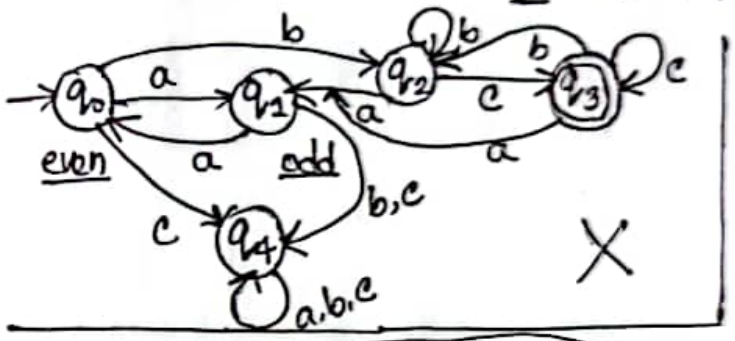
Date :

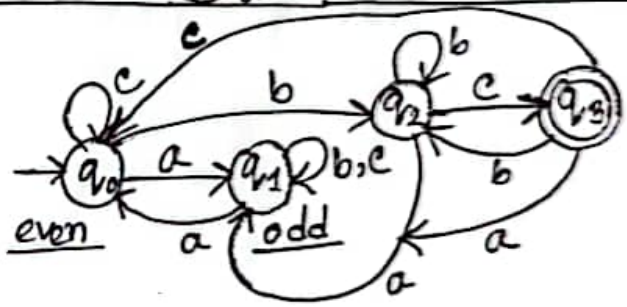
Time :

* starts with even number of a , contains ba , ends with baa.

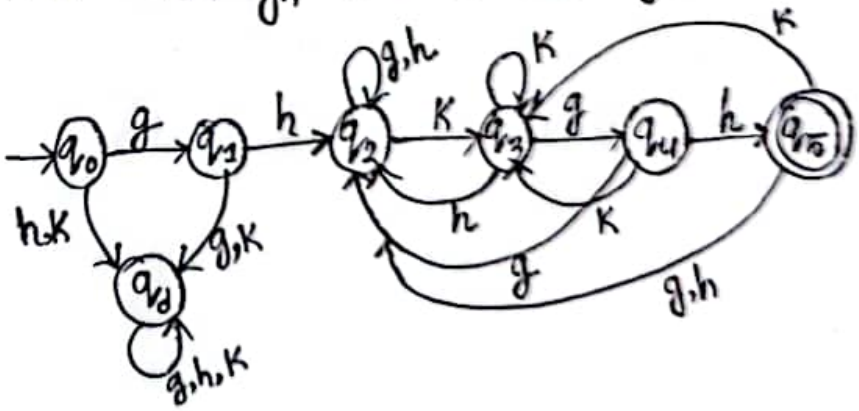


* contain even number of a and ends with bc. $\Sigma = \{a, b, c\}$





* starts with gh and contains kgh and ends with gh .

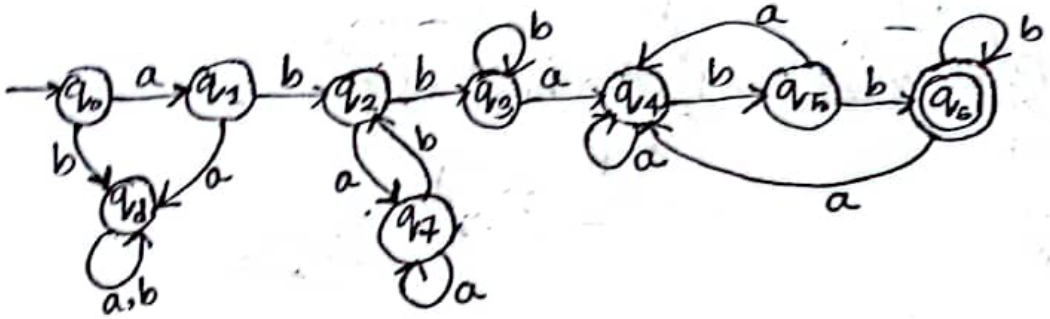


ghkgh

Subject

Date
Time

* starts with ab, contains bba, ends with bb.



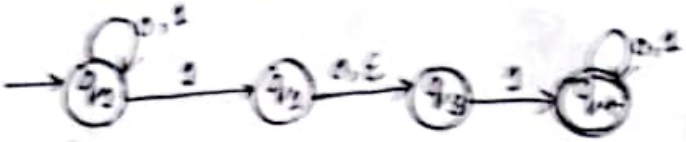
No. 8

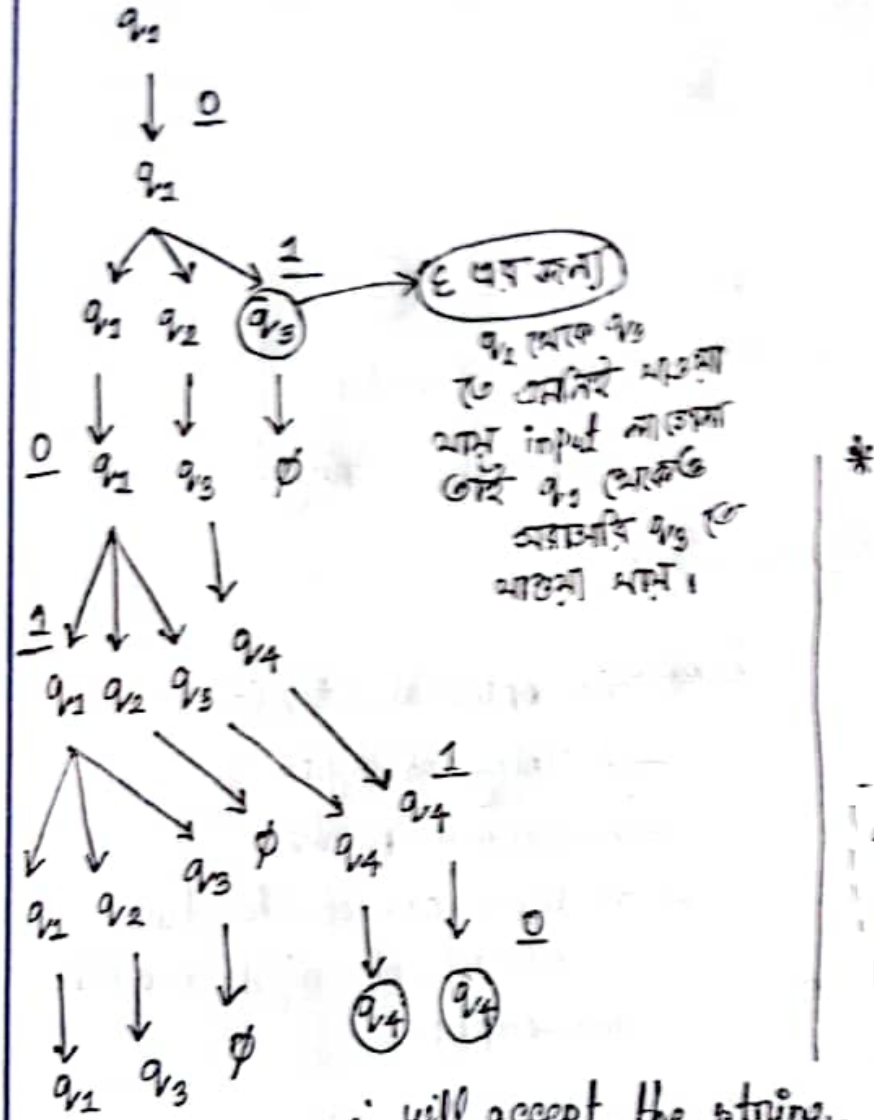
Subject : Epsilon NFA [ε-NFA]

Date :

Time :

String : 010110

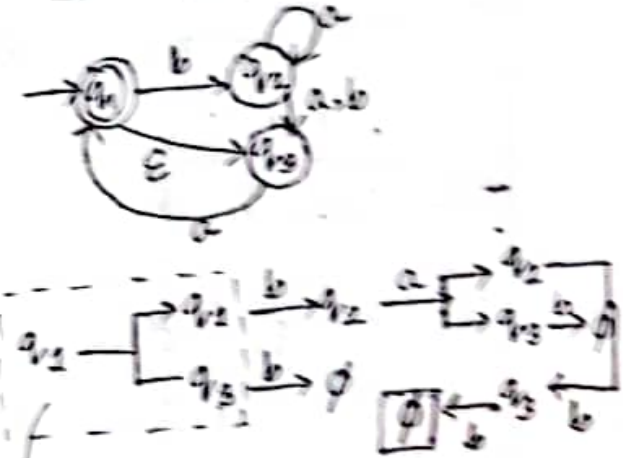




∴ will accept the string.

* কোনো final state থাকলে empty string accept করবে।

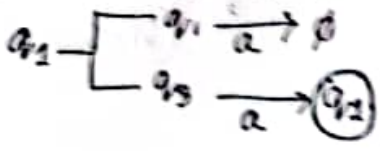
* b a b b a



Start state এই যদি ε থাকে তাহলে ε-close করে নিতে হয় আগে।

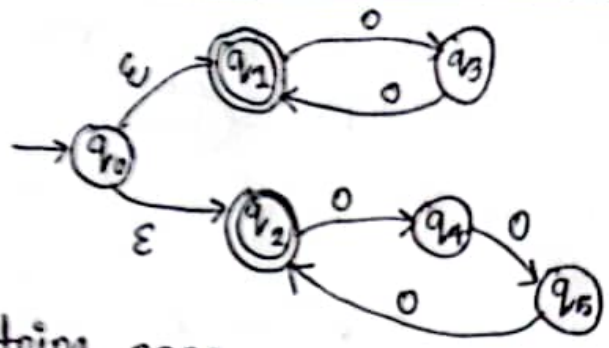
∴ will accept (a).

and accept empty string.



Subject :

Date :
Time :

* 

$\Sigma = \{0\}$; $L = 0^K \mid K$ is a multiple of 2 or 3.

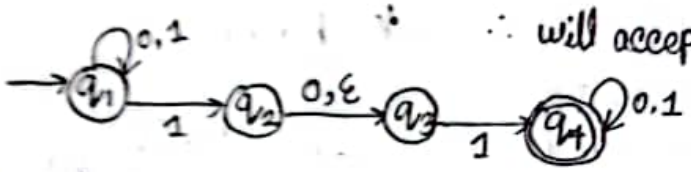
string 0000.

$q_0 \to q_0 \xrightarrow{0} \emptyset$

$q_0 \to q_1 \xrightarrow{0} q_3 \xrightarrow{0} q_1 \xrightarrow{0} q_3 \xrightarrow{0} q_1$

$q_0 \to q_2 \xrightarrow{0} q_4 \xrightarrow{0} q_5 \xrightarrow{0} q_2 \xrightarrow{0} q_4$

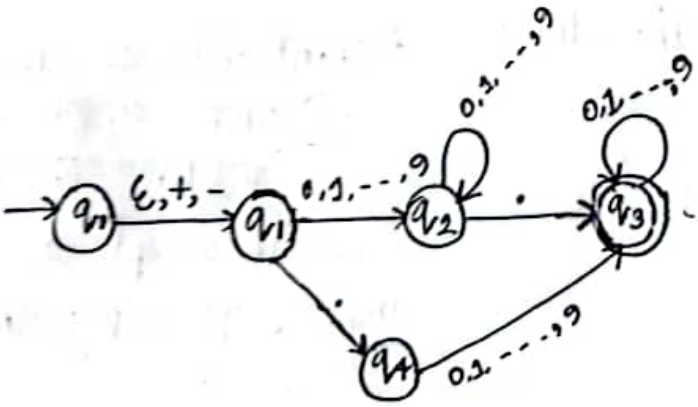
∴ will accept the string.

* 

	0	1	ε
→ q_1	q_1	q_1, q_2	∅
q_2	q_3	∅	q_3
q_3	∅	q_4	∅
* q_4	q_4	q_4	∅

table করার সময় ε ও add হবে।

* → An optional (+)/(-)
→ A string of digits
→ A decimal point
→ at least one of the two strings of digits must be non-empty.



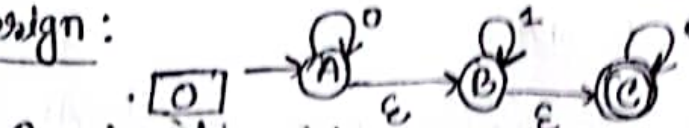
✓ . ✓
x . ✓
✓ . x
} this 3 case will be accepted.

optional
+ 12 . 31 → decimal points
String of digits

Subject :

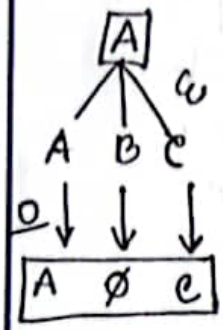
Date
Time

ε-NFA to NFA design :



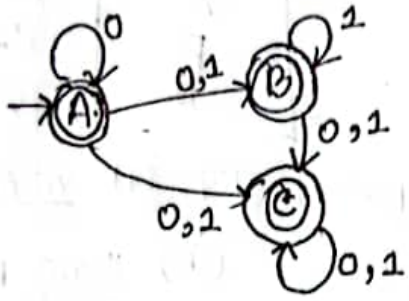
(ε-NFA)

	State	eclose	0	eclose	1	eclose
* →	A	A,B,C	A,C	A,B,C	B,C	B,C
*	B	B,C	C	C	B,C	B,C
*	C	C	C	C	C	C



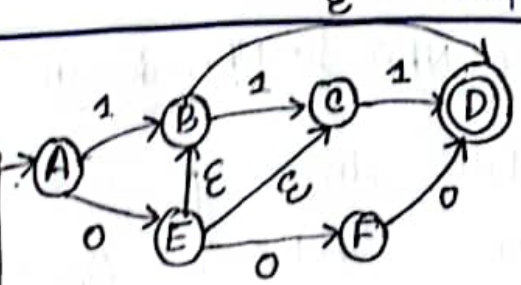
* এখানে final state (C)
∴ eclose এ এখানে (C) আছে
তাহলে তাহলেই final state হবে।

* { 0 & 1 এর জন্য যে কয়টা eclose কে new NFA এর জন্য (0/1) input দিবো।



NFA

ε-NFA to NFA :



State	Eclose()	0	1
→ A	A	E	B
* B	B, D	Ø	C
C	C	Ø	D
* D	D	Ø	Ø
* E	B, C, E, D	F	C, D
F	F	D	Ø

[0] Eclose	[1] Eclose
B, C, E, D	B, D
Ø	C
Ø	D
Ø	Ø
F	C, D
D	Ø

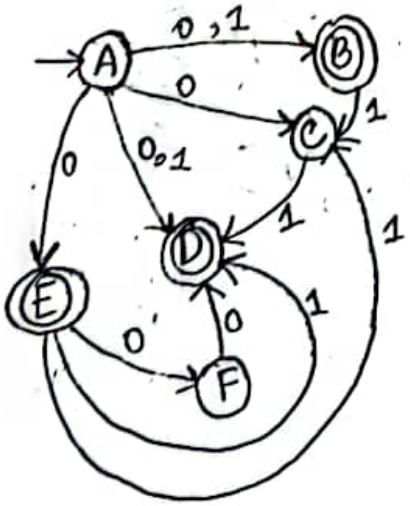
(1) State এর Eclose বের করা।

(2) Eclose থেকে 0/1 এর transition.

(3) [0/1] এ যেই state পাই তার Eclose.

(4) 0/1 এর Eclose কে (0) (1) input হিসেবে ধরা NFA এর জন্য।

(5) 1 no. point এ যার যার Eclose এর মধ্যে Final state থাকবে সেটা main final state হবে।



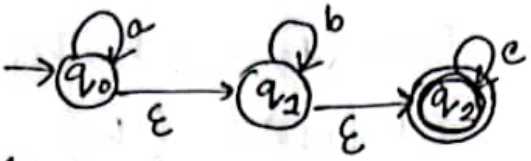
Subject :

Date :
Time :

⊖ ε-NFA to DFA :

(1) ε-NFA → NFA → DFA.

another নিয়ম (2)



Eclose $(q_0) = \{q_0, q_1, q_2\}$

Eclose $(q_1) = \{q_1, q_2\}$

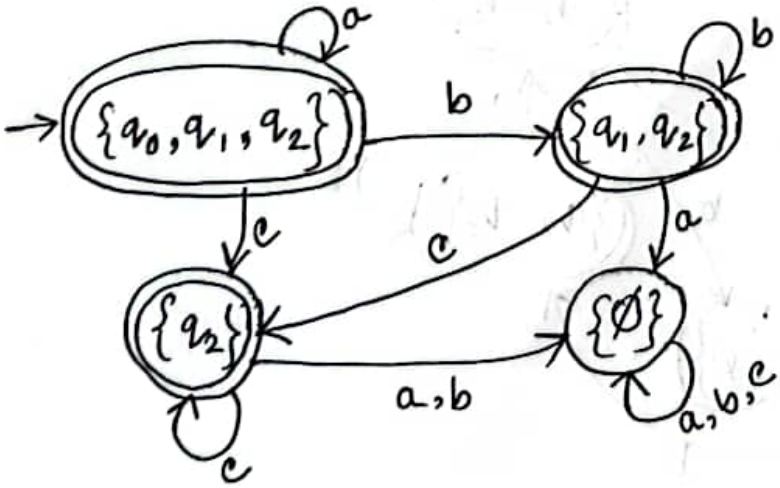
Eclose $(q_2) = \{q_2\}$

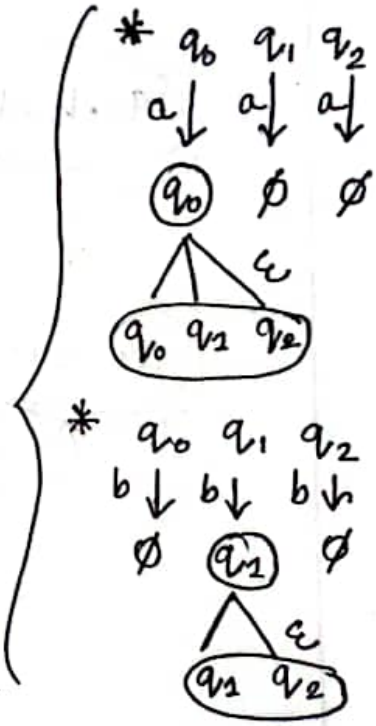
① ε-NFA এর start state এর Eclose হবে DFA এর start state.

② যেসব state এ final state থাকবে সেগুলো main final state হবে।

state \ input	a	b	c
→ * $\{q_0, q_1, q_2\}$	$\{q_0, q_1, q_2\}$	$\{q_1, q_2\}$	$\{q_2\}$
* $\{q_1, q_2\}$	$\{\emptyset\}$	$\{q_1, q_2\}$	$\{q_2\}$
* $\{q_2\}$	$\{\emptyset\}$	$\{\emptyset\}$	$\{q_2\}$
$\{\emptyset\}$	$\{\emptyset\}$	$\{\emptyset\}$	$\{\emptyset\}$

→ input এর জন্য যেই state এ যাবে সেগুলোর eclose.





Subject :

Date :
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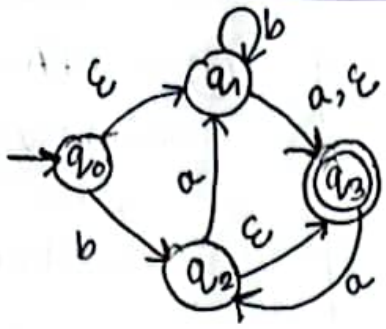


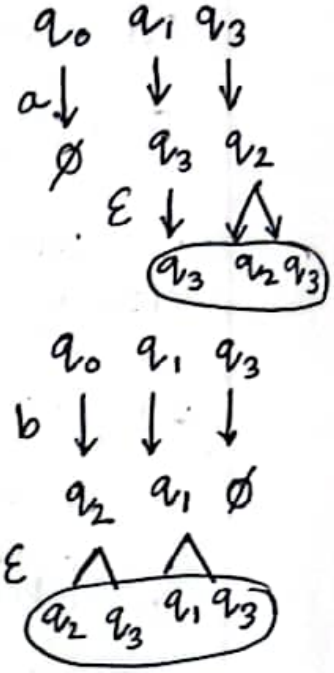
Eclose $(q_0) = \{q_0, q_1, q_3\}$

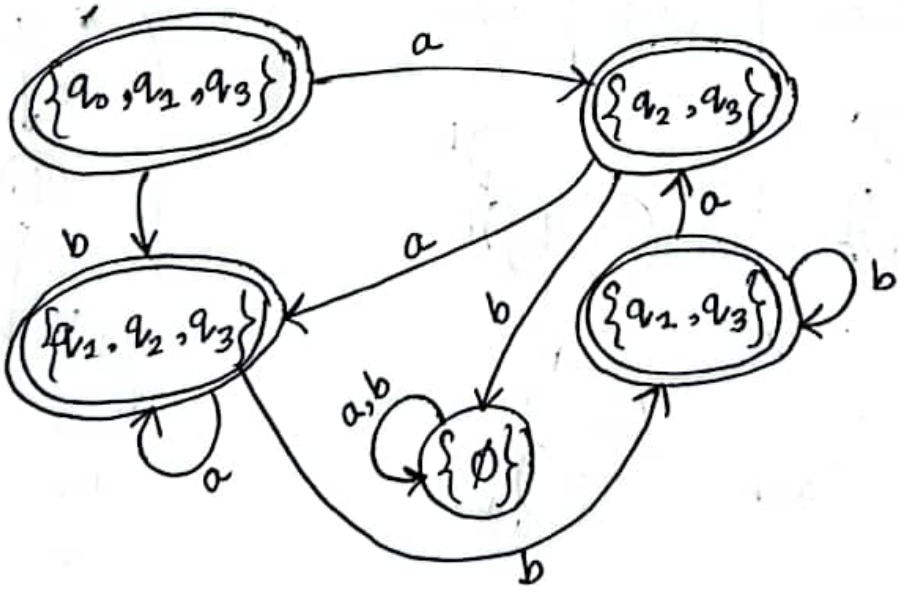
Eclose (q_1) $\{q_1, q_3\}$

Eclose $(q_2) = \{q_2, q_3\}$

Eclose $(q_3) = \{q_3\}$

	a	b
* → $\{q_0, q_1, q_3\}$	$\{q_2, q_3\}$	$\{q_1, q_2, q_3\}$
* $\{q_2, q_3\}$	$\{q_1, q_2, q_3\}$	$\{\phi\}$
* $\{q_1, q_2, q_3\}$	$\{q_1, q_2, q_3\}$	$\{q_1, q_3\}$
$\{\phi\}$	$\{\phi\}$	$\{\phi\}$
* $\{q_1, q_3\}$	$\{q_2, q_3\}$	$\{q_1, q_3\}$





Subject : Regular expression

Date :
Time :

Language থেকে string তৈ বানানো।

* → zero or more times
+ → one or more times

Examples

4. can't contain two consequtive zero's. / every 0 must be followed by at least one 1.
= $1^*(01^+)^*$

5. Even length = $(\Sigma\Sigma)^*$ odd length = $(\Sigma\Sigma)^*\Sigma$

8. starts and ends with same symbol = $0\Sigma^*0 \mid 1\Sigma^*1 \mid 0 \mid 1$
(U) union sign দিলেও হবে।

→ String over {0,1} that ends in 3 consecutive 1's.
Σ^*111 or, $(0|1)^*111$ or, $(0+1)^*111$.

→ at most one 1. = $0^* \mid 0^*10^*$
(1) না থাকা যদি তাহলে
এখানে (0) না হলে ∈ ও হতে পারে।
যেমন: 001 or, 100

→ contains 3 y's. / = $\Sigma^*y\Sigma^*y\Sigma^*y\Sigma^*$ [আগে পরে যেকোনো কিছু আসতে পারে]
contain at least 3 y's.

⊖ contains two consecutive 0's : $\Sigma^*00\Sigma^*$

all except two consecutive 0's : $1^*(01^+)^*$

with an even number of 0's : ~~$\Sigma^*(00)^*\Sigma^*$~~
$(1^*01^*01^*)^*$ [0 একসাথে না থাকলেও হবে even হতে হবে]

Subject :

Date :
Time :

⊖ containing at least one a and at least one b over $\Sigma=\{a,b,c\}$

$= \Sigma^* a \Sigma^* b \Sigma^* \mid \Sigma^* b \Sigma^* a \Sigma^*$ | a, b আগে পরে কোনটা হবে বলা নাই

set of of strings of 0's and 1's whose tenth symbol from the right end is 1.

$= \Sigma^* 1 \Sigma^9$

⊖ not more than one occurrance of the substring aa.

$b^*(ab^+)^* / \; b^*(ab^+)^* aab^+(ab^+)^*$

↙ aa থাকবেইনা।

↘ aa থাকতে পারেনা শুধু a থাকতে পারে।

⊖ does not end with ab.

$= \Sigma^*(aa \mid ba \mid bb)$

⊖ starts with b and ends with b.

$b^* \Sigma b^* \mid b$.

⊖

Subject: Final

Date :
Time :

⊖ regular grammer:

Variable → Variable / terminal
[Capital letter] [Small / digit / other symbol]

*grammer for the strings having a substring 010.

start → S → A

A → 1A | 0A | 010B

B → 1B | 0B | ε

[A/B এগুলো left or right এ থাকে but in CFG variable can be anywhere.]

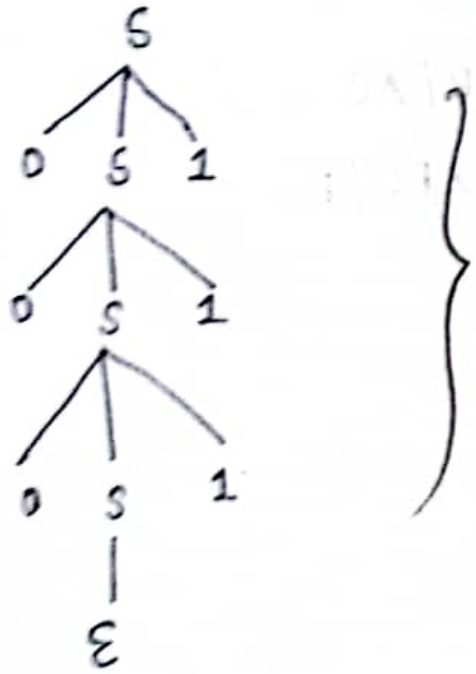
⊖ context - free grammer:

$L = \{0^n 1^n \mid n \geq 0\}$ ⇒ finite দিয়ে solve করা যাচ্ছে না, non-regular language.
↳ context free gram.

$0^0 1^0 = \varepsilon$

$0^1 1^1 = 0011$ → যতটি 0 এর জন্য corresponding 1.

$S \rightarrow 0S1 \mid \varepsilon$ [left most terminal থেকে read করা]



recurrence relation

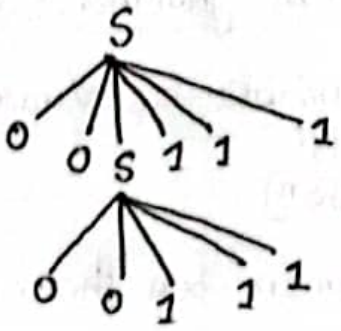
Subject :

Date :
Time :

- $L = \{0^{2n}1^{3n} \mid n \geq 1\}$

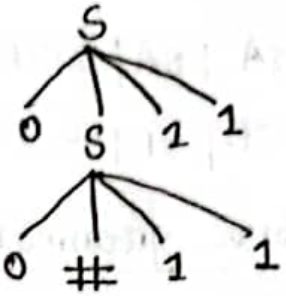
$0^{2\times1}1^{3\times1} = 0^2 1^3 = 00\,111$

$S \rightarrow 00S111 \mid 00111$



- $0^n \# 1^{2n} \mid n \geq 1$

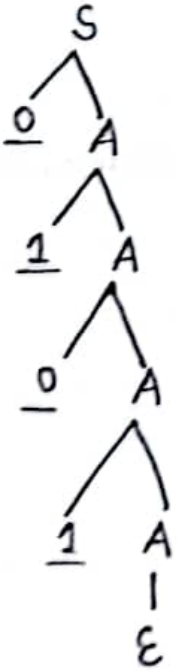
$S \rightarrow 0S11 \mid 0\#11$



- $S \rightarrow 0A$

$A \rightarrow 0A \mid 1A \mid \varepsilon$ } condition

0101 → string



- Numbers without leading zero's; 109 / 0. But not 019.

$A \rightarrow 1/2/3/4/5/6/7/8/9$

$B \rightarrow A/0$

$S \rightarrow B \mid AC$

$C \rightarrow BC \mid B$

Subject

Date

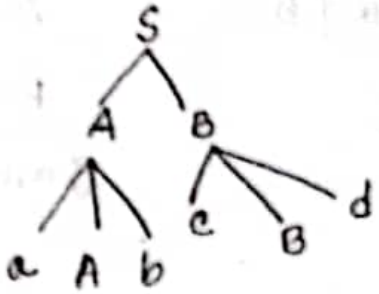
Time

⊜ $L = \{\underbrace{a^n b^n}_{A} \underbrace{c^m d^m}_{B} \mid n \geq 0, m \geq 0\}$

$S \to AB$

$A \to aAb \mid \varepsilon$

$B \to cBd \mid \varepsilon$



⊜ $L = \{a^n b^m c^m d^n \mid n \geq 0, m \geq 0\}$

$S \to aSd \mid B$

$B \to bBc \mid \varepsilon$

$m \geq 1 \Rightarrow$

$S \to aSd \mid aBd$

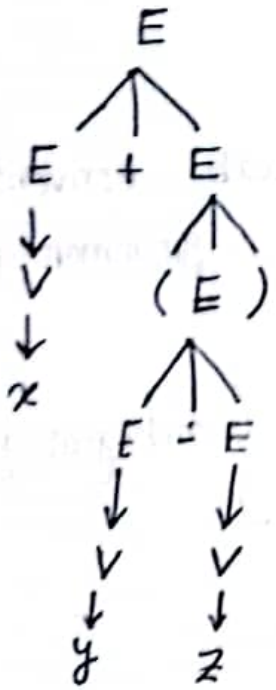
$B \to bBc \mid \varepsilon$

⊟ Parse tree:

$E \to E+E \mid E-E \mid (E) \mid V$

$V \to x \mid y \mid z$

$x + (y - z)$



left most derivation:

$E \Rightarrow E+E$

$\Rightarrow V+E$

$\Rightarrow x+E$

$\Rightarrow x+(E)$

$\Rightarrow x+(E-E)$

$\Rightarrow x+(V-E)$

$\Rightarrow x+(y-E)$

$\Rightarrow x+(y-V)$

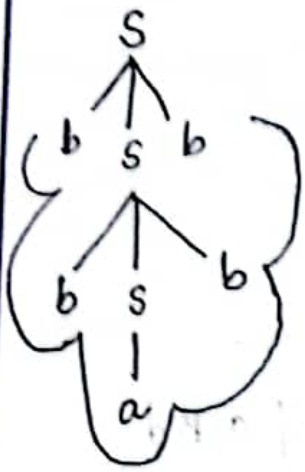
$\Rightarrow x+(y-z)$

Subject :

Date :
Time :

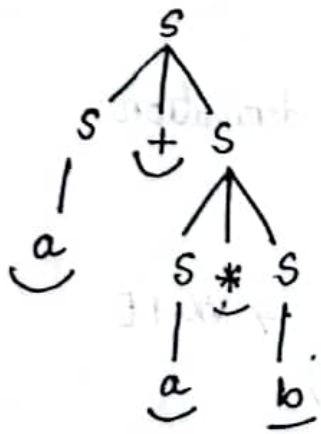
⊖ generate bbabb

$S \rightarrow bSb \mid a \mid b$



⊖ $S \Rightarrow S*S \mid S+S \mid a \mid b$

a+a*b

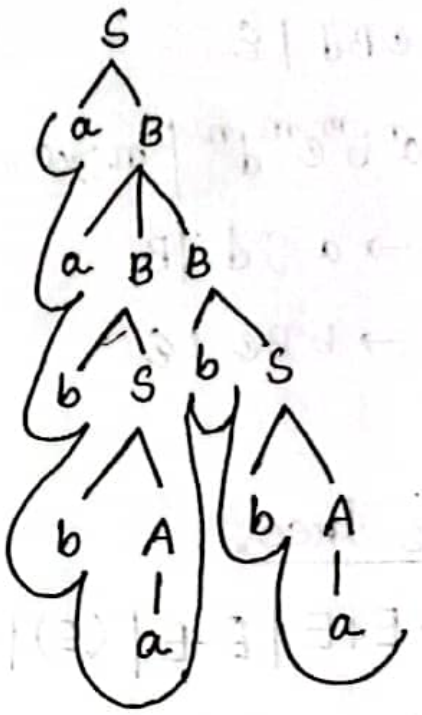


⊖ $S \rightarrow aB \mid bA$

$A \rightarrow a \mid aS \mid bAA$

$B \rightarrow b \mid bS \mid aBB$

generate aabbabba

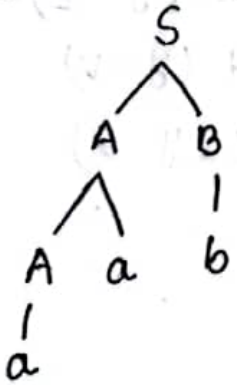


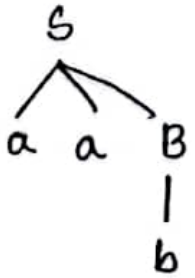
⊖ $S \rightarrow AB \mid aaB$ → Derive the string aab. convert the grammer to unambigous.

$A \rightarrow a \mid Aa$

$B \rightarrow b$

जहाँ तक मिलता unambigous





} ambigous grammers

⊖ $x^i y^j z^{k+1} \mid k = 2j, i \geq 0, j \geq 0$

$= x^i y^j z^{2j+1}$

$= \underbrace{x^i}_{A} \underbrace{y^j z^{2j}}_{B} \cdot \underbrace{z}_{C}$

$S \to ABC$

$A \to xA \mid \in$

$B \to yBzz \mid yzz$

$C \to z$

⊖ $a^m b^n c^u d^v \mid m = n/2, v = u/4$

$= \underbrace{a^m b^{2m}}_{A} \underbrace{c^{4v} d^v}_{B}$

$n = 2m, \; u = 4v$

$S \to AB$

$A \to aAbb \mid abb$

$B \to ccccBd \mid ccccd$

⊖ $L = \{ a^{m+n} c^{3n} d^{2m} \} \mid n, m \geq 2 \mid$

$a^m a^n c^{3n} d^{2m}$

$S \to aSdd \mid aaAdddd$

$A \to aAccc \mid aacccccc$

⊖ $L = \{ ww^R / w \in \{a,b\}^+ \}$ $\quad w = 001$ $\quad w^R = 100$

abb bba

$S \to aSa \mid bSb \mid aa \mid bb$

Subject :

Date :
Time :

Q. $L = \{$odd length starts and ends with same symbol$\}$

$S \rightarrow 0A0 \mid 1A1 \mid 0 \mid 1$

$A \rightarrow 0A0 \mid 0A1 \mid 1A0 \mid 1A1 \mid 0 \mid 1$

odd length

CNF

(a) $S \rightarrow DBC \mid Ba$

$B \rightarrow 0B1 \mid 01 \mid \epsilon$

$C \rightarrow aCb \mid aC \mid Bb$

$D \rightarrow bD \mid D$

Step: 1 $S' \rightarrow S$

$S \rightarrow DBC \mid Ba$

$B \rightarrow 0B1 \mid 01 \mid \epsilon$

$C \rightarrow aCb \mid aC \mid Bb$

$D \rightarrow bD \mid D$

[একমাত্র → যেখানে (S) না থাকলে replace, S' লাগবে না।]

Step: 2 → null removal

$[B \rightarrow \epsilon]$

$S' \rightarrow S$

$S \rightarrow DBC \mid Ba \mid DC \mid a$

$B \rightarrow 0B1 \mid 01 \mid 01$

$C \rightarrow aCb \mid aC \mid Bb \mid b$

$D \rightarrow bD \mid D$

Step: 3 remove unit production

$S' \rightarrow DBC \mid Ba \mid DC \mid a$

$S \rightarrow DBC \mid Ba \mid DC \mid a$

$B \rightarrow 0B1 \mid 01$

$C \rightarrow aCb \mid aC \mid Bb \mid b$

$D \rightarrow bD \mid$ ~~D~~

[Both side এর মধ্যে একই হলে remove]

Step: 4 length ≤ 2

$S' \rightarrow DX \mid Ba \mid DC \mid a$

$X \rightarrow BC$

$S \rightarrow DX \mid Ba \mid DC \mid a$

$B \rightarrow 0Y \mid 01$

$Y \rightarrow B1$

$C \rightarrow aZ \mid aC \mid Bb \mid b$

$Z \rightarrow Cb$

$D \rightarrow bD \mid$ ~~D~~

Subject :

Date :

Time :

Step: 5 terminal

$S' \to DX \mid BP \mid DC \mid a$

$P \to a$

$X \to BC$

$S \to DX \mid BP \mid DC \mid a$

$B \to RY \mid RT$

$R \to 0$

$T \to 1$

$Y \to BT$

$C \to PZ \mid PC \mid BM \mid b$

$M \to b$

$Z \to CM$

$D \to MD \mid \emptyset$

And, $[Z \to \varepsilon]$

$S \to aX \mid bY \mid b \mid ZZc \mid a \mid Zc \mid c$

$X \to Yaa \mid abZ \mid ab$

$Y \to bXXb \mid ab \mid cZ \mid bb \mid c$

$Z \to a \mid b \mid XZ \mid Z \mid X$

Step: 3

$S \to aX \mid bY \mid b \mid ZZc \mid a \mid Zc \mid c$

$X \to Yaa \mid abZ \mid ab$

$Y \to bXXb \mid ab \mid cZ \mid bb \mid c$

$Z \to a \mid b \mid XZ \mid Yaa \mid abZ \mid ab$

Step: 4

$S \to aX \mid bY \mid b \mid ZP \mid a \mid Zc \mid c$

$P \to Zc$

$X \to Ra \mid aT \mid ab$

$R \to Ya$

$T \to bZ$

$Y \to MN \mid ab \mid cZ \mid bb \mid c$

$M \to bX$

$N \to Xb$

$Z \to a \mid b \mid XZ \mid Ra \mid aT \mid ab$

(b) $S \to aX \mid bY \mid b \mid ZZ^{e}c$

$X \to Yaa \mid abZ \mid \varepsilon$

$Y \to bXXb \mid ab \mid cZ$

$Z \to a \mid b \mid XZ \mid \varepsilon$

Step 1 : (X)

Step 2: $[X \to \varepsilon]$

$S \to aX \mid bY \mid b \mid ZZc \mid a$

$X \to Yaa \mid abZ$

$Y \to bXXb \mid ab \mid cZ \mid bb$

$Z \to a \mid b \mid XZ \mid \varepsilon \mid Z$

Subject :

Date
Time

L = {odd length starts and ends with same symbol}

$S \to 0A0 \mid 1A1 \mid 0 \mid 1$

$A \to 0A0 \mid 0A1 \mid 1A0 \mid 1A1 \mid 0 \mid 1$

odd length

CNF

(a) $S \to DBC \mid Ba$

$B \to 0B1 \mid 01 \mid \epsilon$

$C \to aCb \mid aC \mid Bb$

$D \to bD \mid D$

Step: 1 $S' \to S$

$S \to DBC \mid Ba$

$B \to 0B1 \mid 01 \mid \epsilon$

$C \to aCb \mid aC \mid Bb$

$D \to bD \mid D$

Step: 2 → null removal

$[B \to \epsilon]$

$S' \to S$

$S \to DBC \mid Ba \mid DC \mid a$

$B \to 0B1 \mid 01 \mid 01$

$C \to aCb \mid aC \mid Bb \mid b$

$D \to bD \mid D$

Step: 3 remove unit production

$S' \to DBC \mid Ba \mid DC \mid a$

$S \to DBC \mid Ba \mid DC \mid a$

$B \to 0B1 \mid 01$

$C \to aCb \mid aC \mid Bb \mid b$

$D \to bD \mid$ ~~D~~

[Left side এর [illegible]]

Step: 4 length ≤ 2

$S' \to DX \mid Ba \mid DC \mid a$

$X \to BC$

$S \to DX \mid Ba \mid DC \mid a$

$B \to 0Y \mid 01$

$Y \to B1$

$C \to aZ \mid aC \mid Bb \mid b$

$Z \to Cb$

$D \to bD \mid$ ~~D~~

Subject :

Date :
Time :

Step:5 terminal

$S' \to DX \mid BP \mid DC \mid a$

$P \to a$

$X \to BC$

$S \to DX \mid BP \mid DC \mid a$

$B \to RY \mid RT$

$R \to 0$

$T \to 1$

$Y \to BT$

$C \to PZ \mid PC \mid BM \mid b$

$M \to b$

$Z \to CM$

$D \to MD \mid \emptyset$

(b) $S \to aX \mid bY \mid b \mid ZZc$

$X \to Yaa \mid abZ \mid \varepsilon$

$Y \to bXXb \mid ab \mid eZ$

$Z \to a \mid b \mid XZ \mid \varepsilon$

Step1 : (X)

Step2: $[X \to \varepsilon]$

$S \to aX \mid bY \mid b \mid ZZc \mid a$

$X \to Yaa \mid abZ$

$Y \to bXXb \mid ab \mid eZ \mid bb$

$Z \to a \mid b \mid XZ \mid \varepsilon \mid Z$

And, $[Z \Rightarrow \varepsilon]$

$S \to aX \mid bY \mid b \mid ZZc \mid a \mid Zc \mid Zc \mid c$

$X \to Yaa \mid abZ \mid ab$

$Y \to bXXb \mid ab \mid cZ \mid bb \mid c$

$Z \to a \mid b \mid XZ \mid Z \mid X$

Step: 3

$S \to aX \mid bY \mid b \mid 22c \mid a \mid Zc \mid c$

$X \to Yaa \mid abZ \mid ab$

$Y \to bXXb \mid ab \mid eZ \mid bb \mid c$

$Z \to a \mid b \mid XZ \mid Yaa \mid abZ \mid ab$

Step :4

$S \to aX \mid bY \mid b \mid ZP \mid a \mid Zc \mid c$

$P \to Zc$

$X \to Ra \mid aT \mid ab$

$R \to Ya$

$T \to bZ$

$Y \to MN \mid ab \mid eZ \mid bb \mid c$

$M \to bX$

$N \to Xb$

$Z \to a \mid b \mid XZ \mid Ra \mid aT \mid ab$

Subject :

Date :
Time :

Step: 5

$S \to AX \mid BY \mid b \mid ZP \mid a \mid QD \mid c$

$A \to a$

$B \to b$

$D \to c$

$P \to ZD$

$X \to RA \mid AT \mid AB$

$R \to YA$

$T \to BZ$

$Y \to MN \mid AB \mid DZ \mid BB \mid c$

$M \to BX$

$N \to XB$

$Z \to A \mid B \mid XZ \mid RA \mid AT \mid AB$

(c) $S \to a \mid aA \mid B$

$A \to aBB \mid \varepsilon$

$B \to Aa \mid b$

Step: 2

$(A \to \varepsilon)$ $S \to a \mid aA \mid B \mid a$

$A \to aBB$

$B \to Aa \mid b \mid a$

Step: 3

Step: 4

$S \to a \mid aA \mid B \mid a$

$A \to RB$

$P \to aB$

$B \to Aa \mid b \mid a$

Step: 5

$S \to a \mid MA \mid B$

$S \to a \mid aA \mid Aa \mid b \mid a \mid a$

$A \to aBB$

$B \to Aa \mid b \mid a$

Again,

$S \to a \mid aA \mid Aa \mid b$

$A \to aBB$

$B \to Aa \mid b \mid a$

Step: 4

$S \to a \mid aA \mid Aa \mid b$

$A \to aMB$

$M \to aB$

$B \to Aa \mid b \mid a$

Step: 5

$S \to a \mid NA \mid AN \mid b$

$N \to a$

$A \to MB$

$M \to NB$

$B \to AN \mid b \mid a$

Subject :

Date
Time

(d) $q_0 \to 0q_0 \mid 1q_2$

$q_1 \to 0q_3 \mid 1q_0 \mid \varepsilon$

$q_2 \to 0q_1 \mid 1q_3 \mid \varepsilon$

$q_3 \to 0q_4 \mid 1q_1 \mid \varepsilon$

$q_4 \to 0q_2 \mid 1q_4 \mid \varepsilon$

Step-1

$q_0' \to q_0$

$q_0 \to 0q_0 \mid 1q_2$

$q_1 \to 0q_3 \mid 1q_0 \mid \varepsilon$

$q_2 \to 0q_1 \mid 1q_3 \mid \varepsilon$

$q_3 \to 0q_4 \mid 1q_1 \mid \varepsilon$

$q_4 \to 0q_2 \mid 1q_4 \mid \varepsilon$

Step-2 $[q_1 \to \varepsilon]$

$q_0' \to q_0$

$q_0 \to 0q_0 \mid 1q_2$

$q_1 \to 0q_3 \mid 1q_0$

$q_2 \to 0q_1 \mid 1q_3 \mid \varepsilon \mid 0$

$q_3 \to 0q_4 \mid 1q_1 \mid \varepsilon \mid 1$

$q_4 \to 0q_2 \mid 1q_4 \mid \varepsilon$

$[q_2 \to \varepsilon]$

$q_0' \to q_0$

$q_0 \to 0q_0 \mid 1q_2 \mid 1$

$q_1 \to 0q_3 \mid 1q_0$

$q_2 \to 0q_1 \mid 1q_3 \mid 0$

$q_3 \to 0q_4 \mid 1q_1 \mid \varepsilon \mid 1$

$q_4 \to 0q_2 \mid 1q_4 \mid \varepsilon \mid 0$

$[q_3 \to \varepsilon]$

$q_0' \to q_0$

$q_0 \to 0q_0 \mid 1q_2 \mid 1$

$q_1 \to 0q_3 \mid 1q_0 \mid 0$

$q_2 \to 0q_1 \mid 1q_3 \mid 0 \mid 1$

$q_3 \to 0q_4 \mid 1q_1 \mid 1$

$q_4 \to 0q_2 \mid 1q_4 \mid \varepsilon \mid 0$

$[q_4 \to \varepsilon]$

$q_0' \to q_0$

$q_0 \to 0q_0 \mid 1q_2 \mid 1$

$q_1 \to 0q_3 \mid 1q_0 \mid 0$

$q_2 \to 0q_1 \mid 1q_3 \mid 0 \mid 1$

$q_3 \to 0q_4 \mid 1q_2 \mid 1 \mid 0$

$q_4 \to 0q_2 \mid 1q_4 \mid 0 \mid 1$

Step-3

$q_0' \to 0q_0 \mid 1q_2 \mid 1$

$q_0 \to 0q_0 \mid 1q_2 \mid 1$

$q_1 \to 0q_3 \mid 1q_0 \mid 0$

$q_2 \to 0q_1 \mid 1q_3 \mid 0 \mid 1$

$q_3 \to 0q_4 \mid 1q_2 \mid 1 \mid 0$

$q_4 \to 0q_2 \mid 1q_4 \mid 0 \mid 1$

Subject :

Step:4 (length ≤ 2) ✗

Step-5

$Q_0' \rightarrow AQ_0 \mid BQ_2 \mid 1$

$A \rightarrow 0$

$B \rightarrow 1$

$Q_0 \rightarrow AQ_0 \mid BQ_2 \mid 1$

$Q_1 \rightarrow AQ_3 \mid BQ_0 \mid 0$

$Q_2 \rightarrow AQ_1 \mid BQ_3 \mid 0 \mid 1$

$Q_3 \rightarrow AQ_1 \mid BQ_2 \mid 1 \mid 0$

$Q_4 \rightarrow AQ_2 \mid BQ_4 \mid 0 \mid 1$

(c) $S \rightarrow AU \mid BV \mid a \mid b \mid \varepsilon$

$T \rightarrow AU \mid BV \mid a \mid b$

$U \rightarrow TA$

$V \rightarrow TB$

$A \rightarrow a$

$B \rightarrow b$

Step:2

$S \rightarrow AU \mid BV \mid a \mid b$

$T \rightarrow AU \mid BV \mid a \mid b$

$U \rightarrow TA$

$V \rightarrow TB$

$A \rightarrow a$

$B \rightarrow b$

Subject :

Q.(a) $E \to T \mid E+T$

$T \to F \mid T*F$

$F \to I \mid (E)$

$I \to a \mid b \mid Ia \mid Ib \mid I0 \mid I1$

⇒ step ①

$E' \to E$

$E \to T \mid E+T$

$T \to F \mid T*F$

$F \to I \mid (E)$

$I \to a \mid b \mid Ia \mid Ib \mid I0 \mid I1$

step ② = X

step ③ = $E' \to E$, $E \to T$, $T \to F$, $F \to I$

$E' \to a \mid b \mid Ia \mid Ib \mid I0 \mid I1 \mid (E) \mid T*F \mid E+T$

$E \to a \mid b \mid Ia \mid Ib \mid I0 \mid I1 \mid (E) \mid T*F \mid E+T$

$T \to a \mid b \mid Ia \mid Ib \mid I0 \mid I1 \mid (E) \mid T*F$

$F \to a \mid b \mid Ia \mid Ib \mid I0 \mid I1 \mid (E)$

$I \to a \mid b \mid Ia \mid Ib \mid I0 \mid I1$

step ④

$E' \to a \mid b \mid Ia \mid Ib \mid I0 \mid I1 \mid (M \mid TN \mid EL$

$M \to E)$

$N \to *F$

$L \to +T$

$E = a \mid b \mid Ia \mid Ib \mid I0 \mid I1 \mid (M \mid TN \mid EL$

$T = a \mid b \mid Ia \mid Ib \mid I0 \mid I1 \mid (M \mid TN$

$F =$

$+ =$

Subject :

Step ⑤

E = a | b | Ia | IX | IY | IC | ID | OM | TN | EL

X → a

Y → b

C → 0

D → 1

O → (

M → E)

N → *F

L → +T

E = a | b | IX | IY | IC | ID | OM | TN | EL

T =

F =

I =

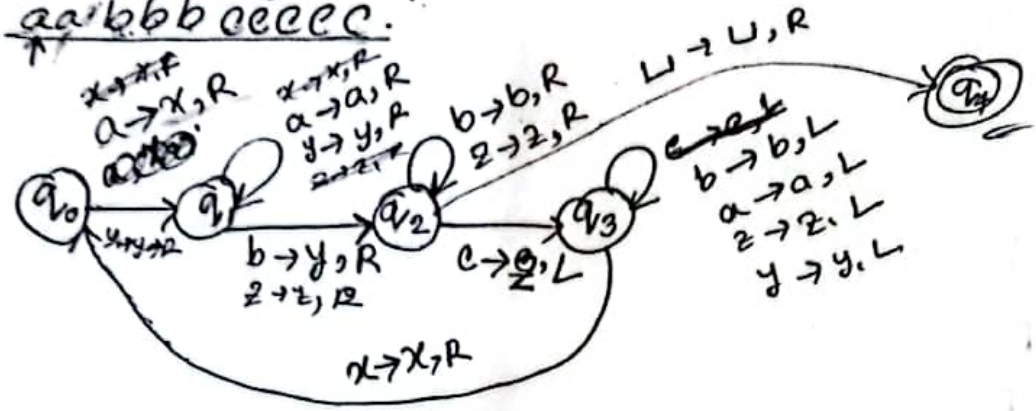
Subject :

Date :
Time :

(TM) Read → change, shift

$L = \{a^i b^j c^k \mid i < j < k,\ i >= 1\}$

x x y y z z
aabbbccccc.



(PDA)

Read, pop → push

CFG {1,0}, contains 110, 010, 011.

(a) $S \rightarrow 1B \mid 0B$

$B \rightarrow 1BO \mid 0B1 \mid 1B \mid 0B \mid 1 \mid 0 \mid \varepsilon$

(b) binary number divisible by 4 :

0, 4, 8, 12, ---

0 100 1000 → ends with (0).

$S \rightarrow 1A0 \mid 0A0 \mid 0$

$A \rightarrow 1A \mid 0A \mid 0 \mid \varepsilon$

Subject : $x^{2n} y^{mn} z^{mn}$ $n=1, m=1$ $\Rightarrow y^{mn} z^{mn}$

Date :

Time :

(c) $\{ \underbrace{x^{2n}}_{A} \underbrace{(y^m z^m)^n}_{B} \}$ $m, n \geq 0$ | $xx(yz)^n$ | $xxxx\,yyzz$

$S \rightarrow xxSB \mid \varepsilon$

$B \rightarrow yBz \mid \varepsilon$

$xxxx\,yzyz$

$S \rightarrow AB$

$A \rightarrow xAx \mid \varepsilon$

$B \rightarrow$

(d) $a^n b^m c^p$ | $a^2 b^3 c^4$ | $a^3 b^2 c^4$

A B

$aabbbcccc$

$S \rightarrow AB$

$A \rightarrow aaAbbb \mid aaaAbb \mid aabbb \mid aaabb$

$B \rightarrow cB \mid cccc$