

UNIT - 4

* Turing Machine (TM) *

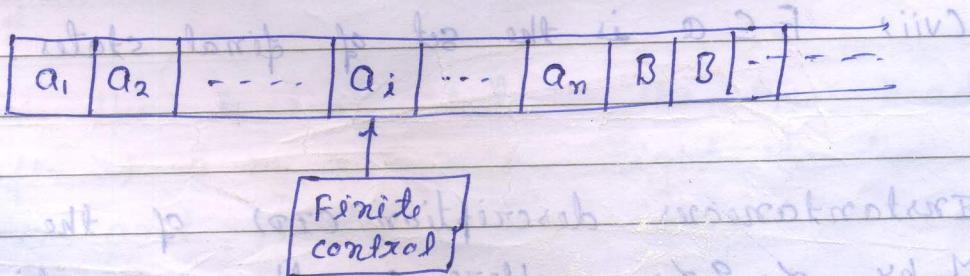
The Turing Machine is a simple mathematical model of general purpose computer. Turing Machine is a language acceptor as well as it is capable of performing any calculation which can be performed by any computing machine.

* Model of TM *

The basic model has a finite control, an input tape that is divided into cells, and a tape head that scans one cell of the tape at a time. The tape has a leftmost cell but is infinite to the right.

Each cell of the tape may hold exactly one of a finite number of tape symbols.

Initially, the n leftmost cells, for some finite $n \geq 0$, hold the input. The remaining infinity of cells each hold the blank, which is a special tape symbol that is not an input symbol.



Basic Turing machine.

(2)

In one move the Turing machine, depending upon the symbol scanned by the tape head and the state of the finite control,

- 1.) Changes state,
- 2.) Prints a symbol on the tape cell scanned, replacing what was written there,
- 3.) Move its head left or right one cell.

* * Definition * *

A Turing machine (TM) is denoted

(i) α is the finite set of states,

(ii) Σ is the finite set of allowable tape symbols,

(iii) B , a symbol of Γ , is the blank,

(iv) δ , a mapping from $\alpha \times \Gamma$ to $\alpha \times \Gamma \times \{L, R\}$, is the next move function,

(v) z_0 in α is the start state,

(vi) $F \subseteq \alpha$ is the set of final states.

* Instantaneous description (ID) of the Turing Machine M by $z_1 z_2$. Here z_1 the current state of M, is in α ;

$z_1 z_2$ is the string in Γ^*

(3)

Moves to initial state at the start of the work tape.
Let $x_1 x_2 \dots x_{i-1} x_i \# x_{i+1} \dots x_n$ be an ID. HT

(1) Suppose $\delta(2, x_i) = (P, Y, L)$. Then change of ID is represented by $x_1 x_2 \dots x_{i-1} P x_{i+1} \dots x_n$.

$x_1 x_2 \dots x_{i-1} x_i \# x_{i+1} \dots x_n \xrightarrow{\text{print } M} x_1 x_2 \dots x_{i-1} P x_{i+1} \dots x_n$

(2) Suppose $\delta(2, x_i) = (P, Y, R)$. Then change of ID is represented by $x_1 x_2 \dots x_{i-1} Y P x_{i+1} \dots x_n$.

$x_1 x_2 \dots x_{i-1} x_i \# x_{i+1} \dots x_n \xrightarrow{\text{print } M} x_1 x_2 \dots x_{i-1} Y P x_{i+1} \dots x_n$

Turing Machine (Language acceptor)

(a) The design of a TM M to accept the language
 $L = \{0^n 1^n \mid n \geq 1\}$

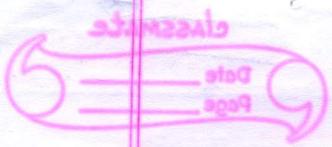
Solution:- Initially the tape of M contains $0^n 1^n$ followed by an infinity of blanks.

Compare 0's and 1's. first compare first zero to first one.
& so on.

Design:-

Step 1:- z_0 is the initial state. The R/W head replaces the leftmost 0 by X, moves right to the leftmost 1. Replace and moves to the right. TM enters z_1 .

Step 2:- Moves right to the leftmost 1, the R/W head replaces 1 by Y and moves to the left. TM enters z_2 .



Step 3: - Moves left to find the rightmost x, then moves one cell right to the leftmost 0 . and TM enters ~~on~~ and repeats ~~the~~ cycle $x, x \rightarrow$

Step 4:- If however, (when) searching for accept, M finds a blank instead, then M halts without accepting.

$$x_7 \cdot x_8 \cdot x_9 = x_7 \cdot x_8 + x_7 \cdot x_9 - x_8 \cdot x_9$$

If M finds no more 0's then M checks that no more 1's remain, accepting if there are none.

Input String B00001111B

6

B X X X Y Y Y Y B

下下

$$+2x^9y - 2xy^{14}z^R - x^2y^R + xy - 2xz^8 \frac{\uparrow\uparrow}{z^2z^2} - \frac{\uparrow\uparrow}{z_1z_2} x^2y^R - x^2y^R$$

105 11

$$0/t^*, R \rightarrow L$$

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ОГЛАСКАВАЮЩИЕ МОЧЕВЫЕ ПРИВЫКНОВЕННЫЕ

$$\rightarrow (x_0) \times \lim_{n \rightarrow \infty} x/x_n B = 0 \quad y/y_n B$$

Y1 = $\frac{1}{2} \sin(2\pi f_1 t) + \frac{1}{2} \cos(2\pi f_2 t)$

Y, R

χ/χ_{RBC} < 4 to spot out ellipticity

strated to strengthen me up

coupling of α , β and γ . If $B_1/B_2 \gg 1$, then B_1 dominates.

- 1081290

24

so that the state foistered on it is as

- Transistor diagram:

THE BIG ONE OF AVANT BIRD WATCHING

118 out of 130 total edit of ENRAC WORK

- Had 2nd at senior high & 3rd at college

• 8 visitors

(5)



Transition Table:

state	symbol			
	0	1	x	y
$\rightarrow q_0$	(q_1, x, R)			(q_3, Y, R)
q_1	$(q_1, 0, R)$	(q_2, Y, L)		(q_1, Y, R)
q_2	$(q_2, 0, L)$		(q_0, X, R)	(q_2, Y, L)
q_3				(q_3, Y, R)
q_4				(q_4, B, R)

Here

$$\Omega = \{q_0, q_1, q_2, q_3, q_4\}$$

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

$$\Gamma = \{0, 1, x, y, B\}$$

$$F = \{q_4\}$$

(S. 83, 8.03, the functioning of machine M is defined as:-

- hold DT without reset in binary at 3.

$$M = (\{\Omega, \Sigma, \Gamma, F\}, \delta, q_0, B, \{q_4\}).$$

where δ is defined as:-

δ is defined in Transition Table.

$$\delta(q_0, 0) = (q_1, x, R)$$

$$\delta(q_2, x) = (q_0, X, R)$$

$$\delta(q_0, Y) = (q_3, Y, R)$$

$$\delta(q_2, Y) = (q_2, Y, L)$$

$$\delta(q_1, 0) = (q_1, 0, R)$$

$$\delta(q_3, Y) = (q_3, Y, R)$$

$$\delta(q_1, 1) = (q_2, Y, L)$$

$$\delta(q_3, B) = (q_4, B, R)$$

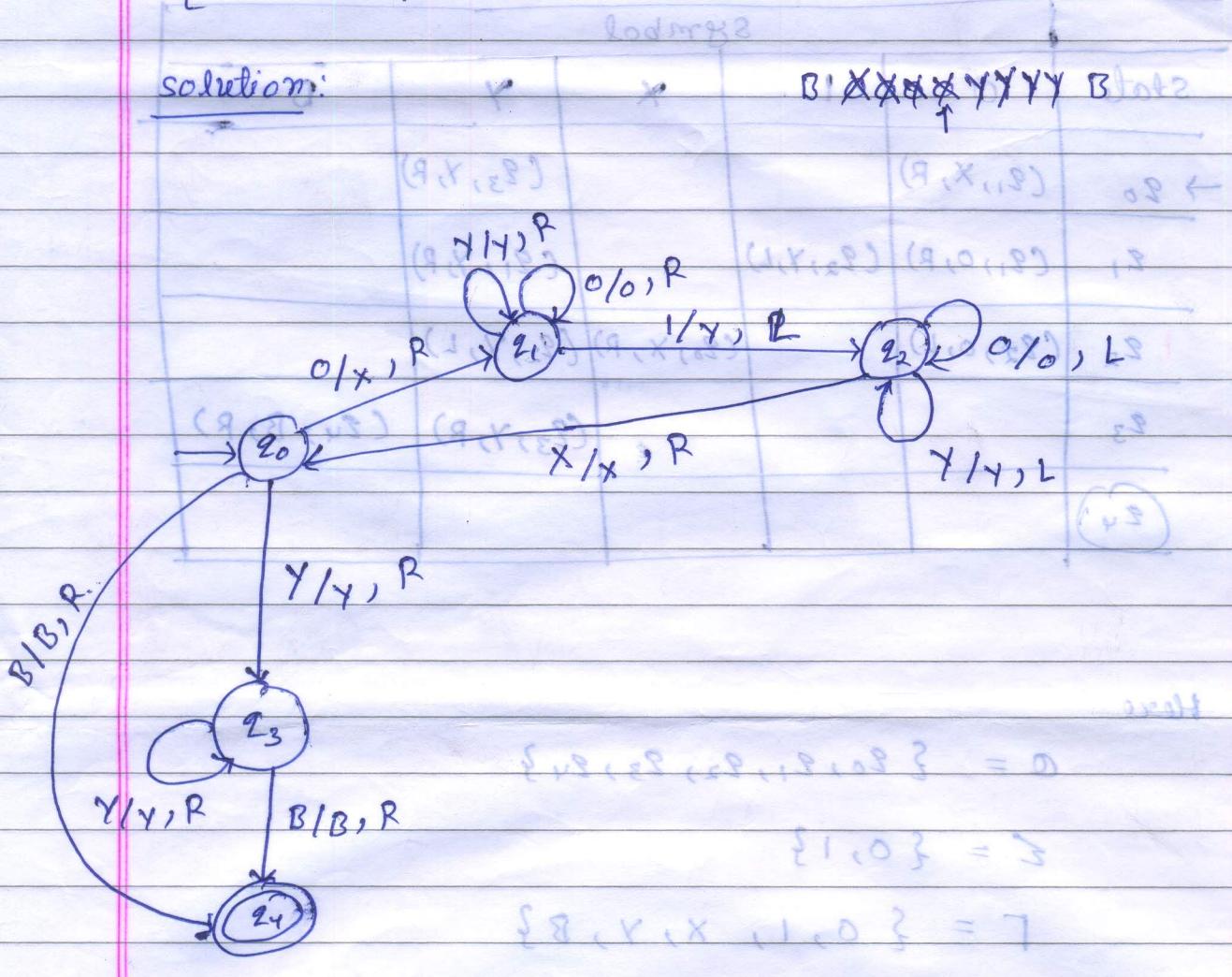
$$\delta(q_1, Y) = (q_1, Y, R)$$

$$\delta(q_2, 0) = (q_2, 0, L)$$

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(Q2) Design Turing Machine to recognize the language
 $\{0^n 1^n \mid n \geq 0\}$.

solution:



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

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

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

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

$M = (\{q_0, q_1, q_2, q_3, q_4\}, \{0, 1\}, \{x, y, B\}, \delta, q_0, B, \{q_4\})$, δ is defined in Transition Table:-

state / symbol	0	1	x	y	B
$\rightarrow q_0$	(q_1, x, R)			(q_3, y, R)	(q_4, B, R)
(q, x, q_1)	$(q_1, 0, R)$	(q_2, y, L)	(q_1, x, R)	(q_1, y, R)	
(q, y, q_2)	$(q_2, 0, L)$		(q_0, x, R)	(q_2, y, L)	
(q, B, q_3)			(q_3, y, R)	(q_4, B, R)	
q_4	-	-	(q_4, x, R)	(q_4, y, R)	(q_4, B, R)



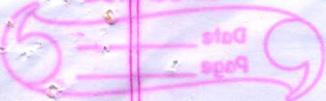
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(7)

start

dots
dots
dots

(2)



Input string 0011 is given to the state

Initial int at start bco X gd Σ woldse

$$\begin{array}{l} 2_0 \ 0011 \xrightarrow{\quad} X_2, 011 \\ \quad \quad \quad \xrightarrow{\quad} X_02, 11 \end{array}$$

Input w18 int + 8 → X_2, 0Y1 given to the state

Initial int at start bco X gd Σ woldse

$$\begin{array}{l} \xrightarrow{\quad} X_2, 0Y1 \text{ int } M \\ \quad \quad \quad \xrightarrow{\quad} XX_2, Y1 \end{array}$$

int a brief ti. This XX, Y2 int M is the final state

Initial w18 int + 8 → X_2, 0Y1 bco X_2, 0Y1 is accepted

$$\begin{array}{l} \xrightarrow{\quad} X_2, XYY \text{ bco ringo} \end{array}$$

Initial int + 8 → X_2, 0YY ringo ti bco

Initial int + 8 → X_2, 0YY ringo ti bco

$$\begin{array}{l} \xrightarrow{\quad} X_2, XYY \text{ int bco} \\ \quad \quad \quad \xrightarrow{\quad} XX_2, Y \text{ int bco} \end{array}$$

$$\begin{array}{l} \xrightarrow{\quad} XX_2, Y \text{ int bco} \\ \quad \quad \quad \xrightarrow{\quad} XXYY_2 \text{ bco ringo} \end{array}$$

$$\begin{array}{l} \xrightarrow{\quad} XXYY_2 \text{ bco ringo} \\ \quad \quad \quad \xrightarrow{\quad} XXYYB_2 \end{array}$$

brief ti. print giving grilofse raffa

Here Turing Machine has reached final state
24, this input string 0011 is accepted.

1 1 1 2 2 2 3 3 3 B

(3)

Design Turing Machine to recognize the language $\{1^n 2^n 3^n \mid n \geq 1\}$.

Solution:-

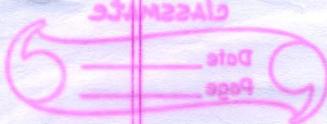
Let us take 111222333B

compare 1, 2 & 3. first compare first 1, first 2 and first 3. & so on.

Design:-

Step 1: 20 is the initial state. The R/W head scans the leftmost 1, replaces 1 by X and moves to the right. TM enters 21.

- : after reading -



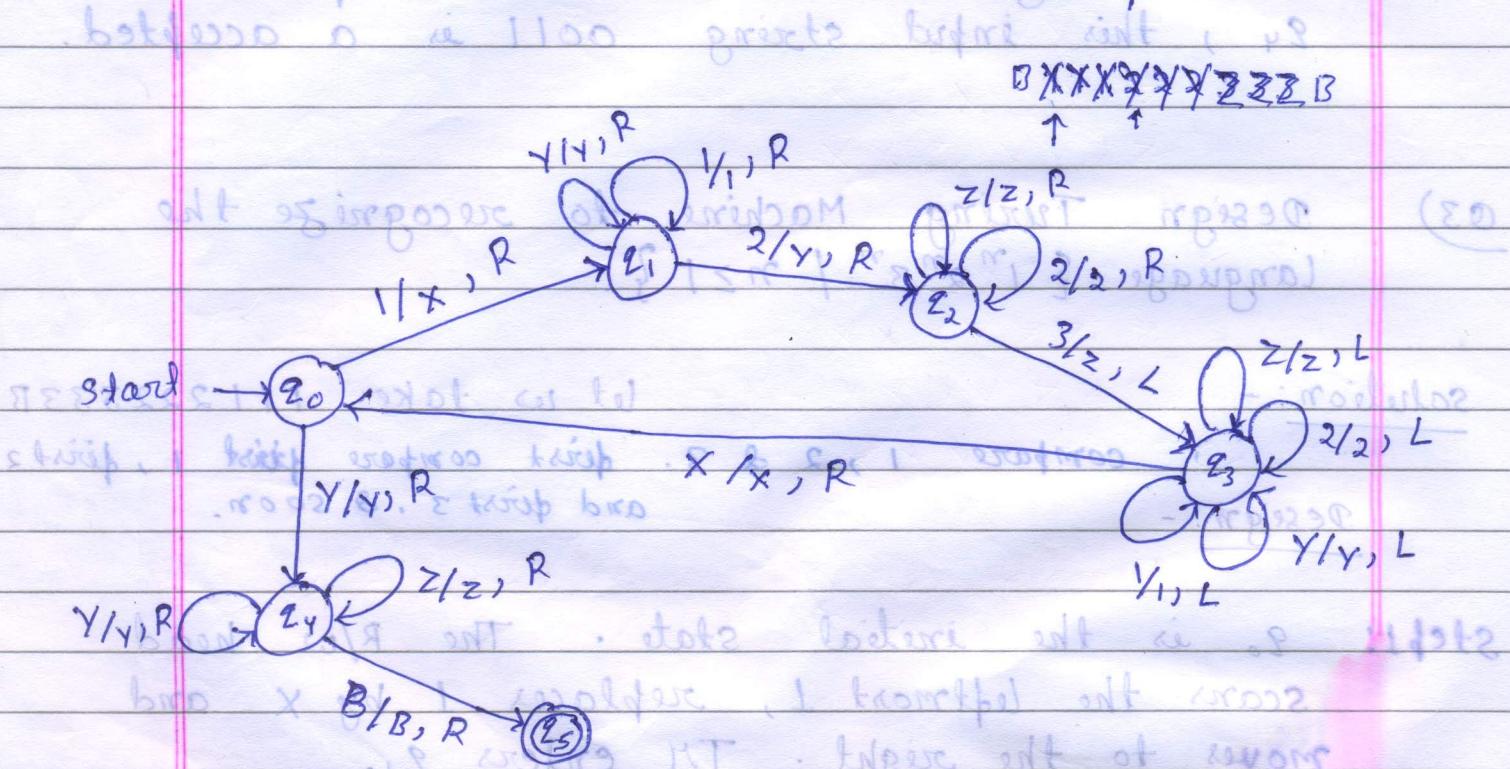
(8)

step 2: on scanning the leftmost 2, the R/w head replaces 2 by Y and moves to the right. TM enters q_2 . $110, S X \rightarrow 1100, S$
 $11, S 0 X \rightarrow$

step 3: on scanning the leftmost 3, the R/w head replaces 3 by Z and moves to the left. M enters q_3 . $1Y0, S X \rightarrow$
 $1Y, S XX \rightarrow$

step 4: It will move left until it finds the leftmost 3 and then it will move right again and enters q_0 .
 and it again scans the Repeat step 1 to 4.
 and the process goes on until all strings are replaced by X, YX and Z.

step 5: After replacing every string it finds blank, but it will enter into final state.



- Transition graph:-



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Transition & Table :-

symbol

state	1	2	3	x	y	z	B
$\rightarrow q_0$	(q_1, x, R)	-	-	-	(q_4, Y, R)	-	-
q_1	$(q_1, 1, R)$	(q_2, Y, R)	-	-	(q_1, Y, R)	-	-
q_2	-	$(q_2, 2, R)$	(q_3, Z, L)	-	-	(q_2, Z, R)	-
q_3	$(q_3, 1, L)$	$(q_3, 2, L)$	$(q_4, -)$	(q_0, X, R)	(q_3, Y, L)	(q_3, Z, L)	-
q_4	-	-	-	-	(q_4, Y, R)	(q_4, Z, R)	(q_5, B, R)
q_5	-	-	-	-	-	-	-

Transition & Rules :-

$$\delta(q_0, 1) = (q_1, x, R)$$

$$\delta(q_0, Y) = (q_4, Y, R)$$

$$\delta(q_1, 1) = (q_1, 1, R)$$

$$\delta(q_1, 2) = (q_2, Y, R)$$

$$\delta(q_1, Y) = (q_1, Y, R)$$

$$\delta(q_2, 2) = (q_2, 2, R)$$

$$\delta(q_2, 3) = (q_3, Z, L)$$

$$\delta(q_2, Z) = (q_2, Z, R)$$

$$\delta(q_3, 1) = (q_3, 1, L)$$

$$\delta(q_3, 2) = (q_3, 2, L)$$

$$\delta(q_3, X) = (q_0, X, R)$$

$$\delta(q_3, Y) = (q_3, Y, L)$$

$$\delta(q_3, Z) = (q_3, Z, L)$$

$$\delta(q_4, Y) = (q_4, Y, R)$$

$$\delta(q_4, Z) = (q_4, Z, R)$$

$$\delta(q_4, B) = (q_5, B, R)$$

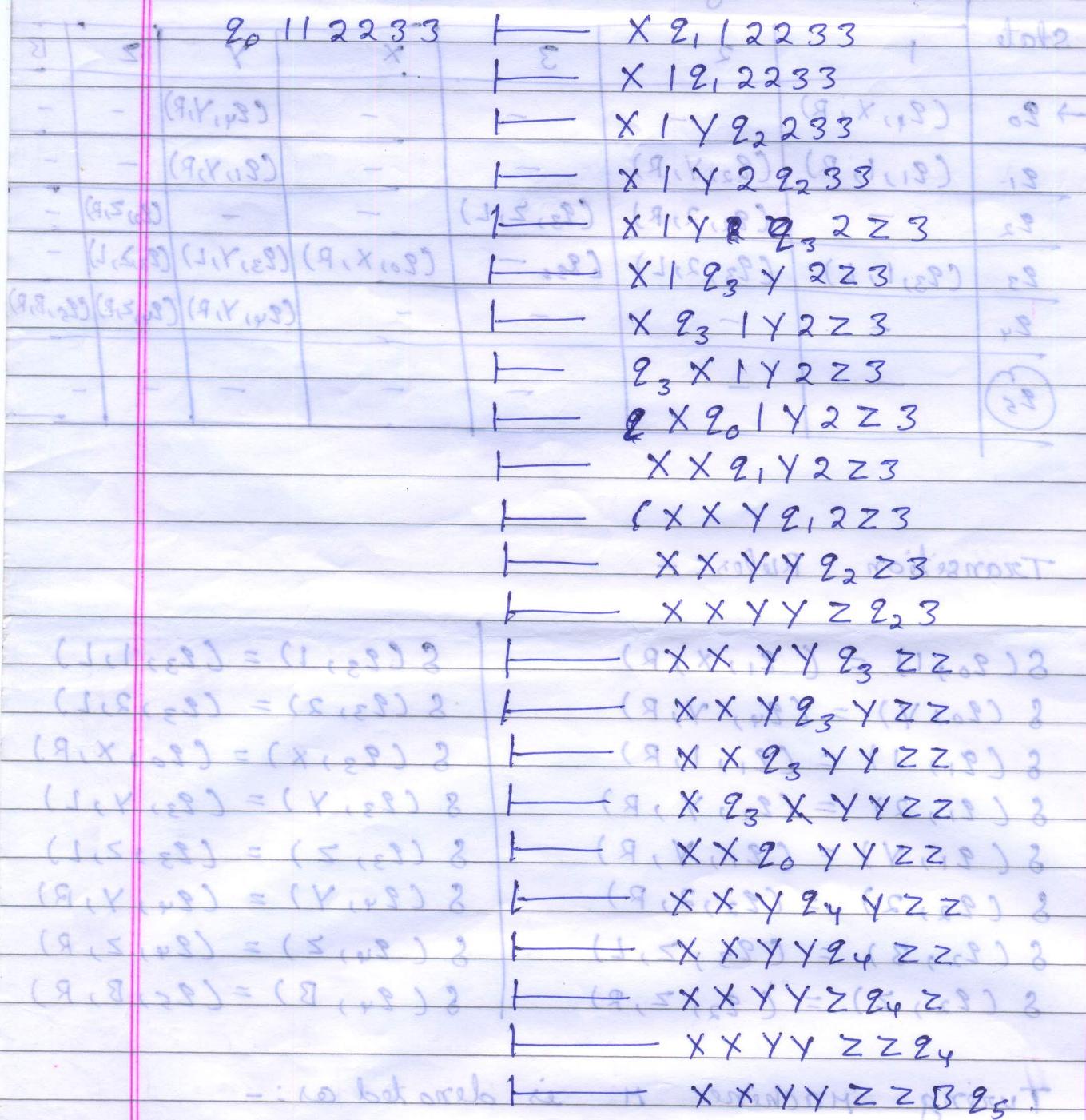
Turing Machine M is denoted as :-

$$M = (\{q_0, q_1, q_2, q_3, q_4, q_5\}, \{1, 2, 3, X, Y, Z, B\}, \delta, q_0, B, \{q_5\}).$$

δ is defined above.

Check the string - 112233. not correct

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- no better \rightarrow X X Y Y Z Z 23, 223

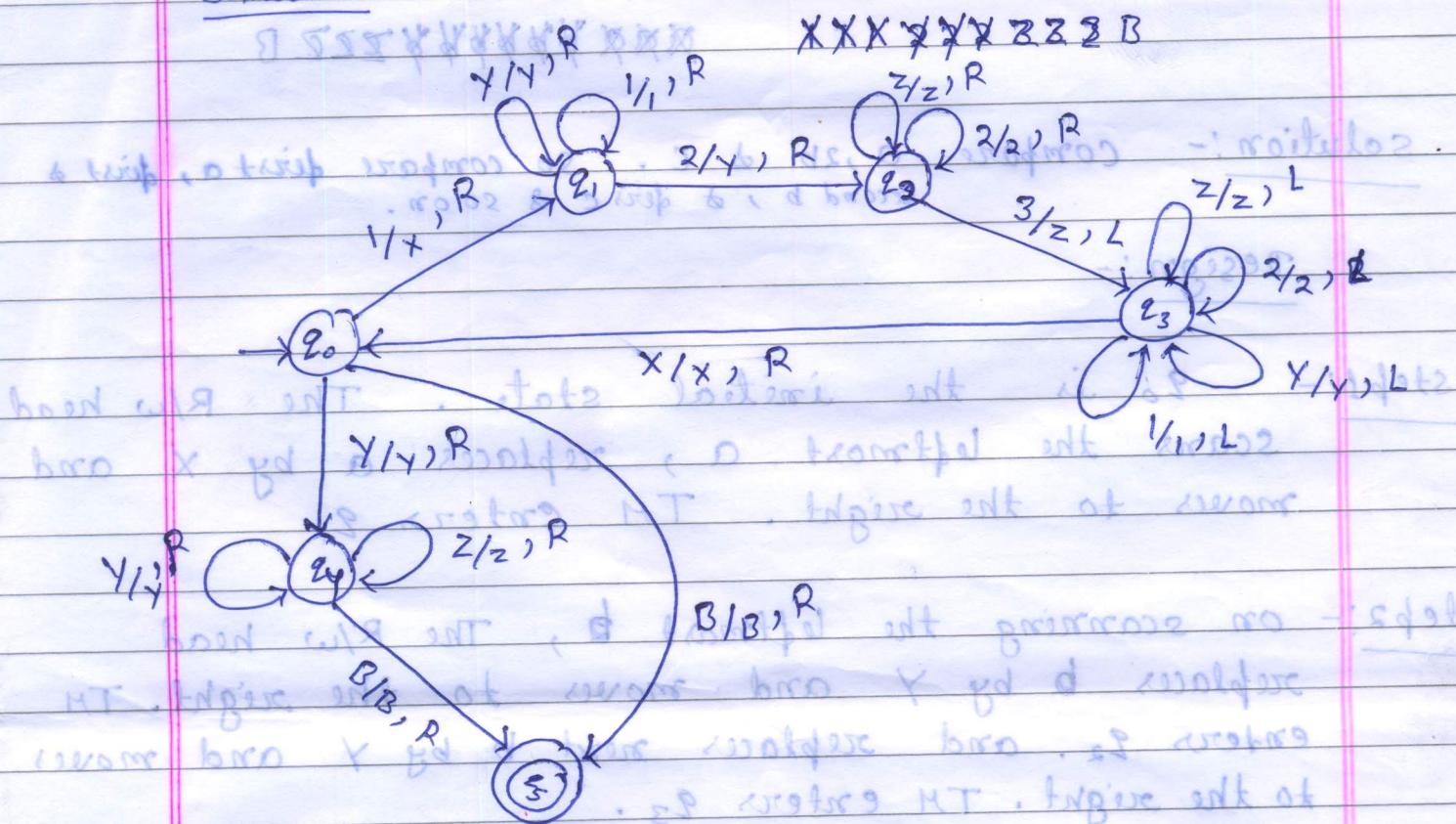
{S, S X 25} is final state so it accept) the string.
(1283, 8, 25, 13)

words accepted = 8



Q4) Design a Turing Machine to recognize the language
 $\{1^n 2^n 3^n \mid n \geq 0\} \cup \{1^n 2^n 3^n \mid n \geq 0\}$

Solution:-



Turing Machine M is denoted as -
 $M = (\{q_0, q_1, q_2, q_3, q_4, q_5\}, \{1, 2, 3\}, \{X, Y, Z, B\}, \{q_0, B\}, \{q_5\})$

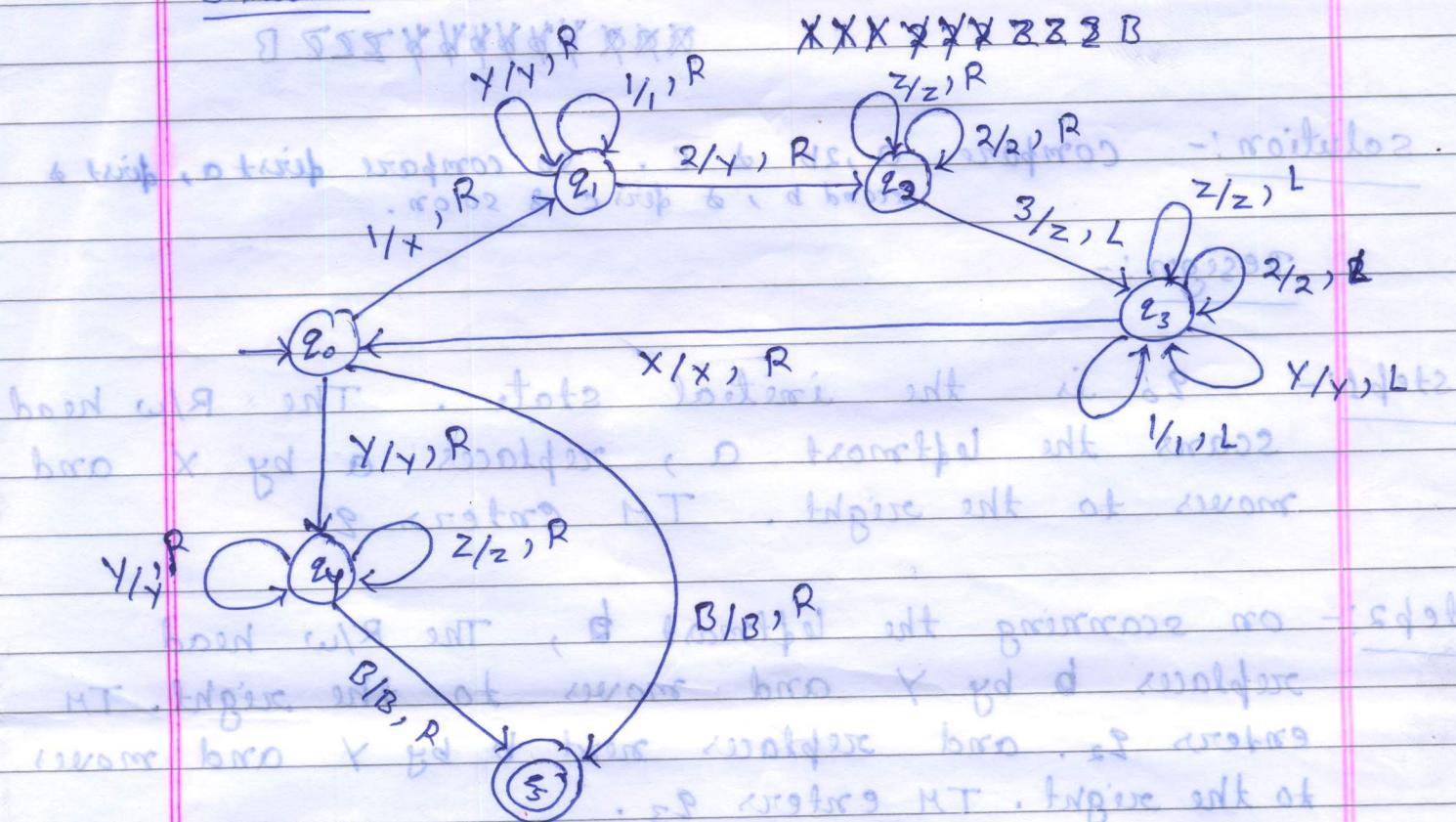
X in S is defined in transition Table. T.T. :-

State.	1	2	3	X	Y	Z	B
$\rightarrow q_0$	(q_1, X, R)	-	-	-	(q_4, Y, R)	-	(q_5, B, R)
q_1	$(q_1, 1, R)$	(q_2, Y, R)	-	-	(q_1, Y, R)	-	-
q_2	-	$(q_2, 2, R)$	(q_3, Z, L)	-	-	(q_2, Z, R)	-
q_3	$(q_3, 1, L)$	$(q_3, 2, L)$	-	(q_0, X, R)	(q_3, Y, L)	(q_3, Z, L)	-
q_4	-	-	-	-	(q_4, Y, R)	(q_4, Z, R)	(q_5, B, R)
q_5	-	-	-	-	-	-	-



Q4) Design a Turing Machine to recognize the language
 $\{1^n 2^n 3^n \mid n \geq 0\} \cup \{1^n 2^n 3^n \mid n \geq 0\}$

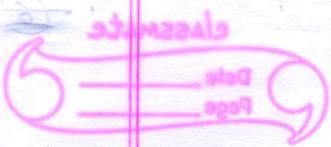
Solution:-



Turing Machine M is denoted as -
 $M = (\{q_0, q_1, q_2, q_3, q_4, q_5\}, \{1, 2, 3\}, \{X, Y, Z, B\}, \{q_0, B, \{q_5\}\})$

X in S is defined in transition Table. T1 :-

State	1	2	3	X	Y	Z	B
$\rightarrow q_0$	(q_1, X, R)	-	-	-	(q_4, Y, R)	-	(q_5, B, R)
q_1	$(q_1, 1, R)$	(q_2, Y, R)	-	-	(q_1, Y, R)	-	-
q_2	-	$(q_2, 2, R)$	(q_3, Z, L)	-	-	(q_2, Z, R)	-
q_3	$(q_3, 1, L)$	$(q_3, 2, L)$	-	(q_0, X, R)	(q_3, Y, L)	(q_3, Z, L)	-
q_4	-	-	-	-	(q_4, Y, R)	(q_4, Z, R)	(q_5, B, R)
q_5	-	-	-	-	-	-	-



(11)

(12)

- (Q5) Design Turing Machine to recognize the language
 $\{a^n b^n c^n \mid n \geq 0\}.$

~~A B C D E F G H I J K L M N O P Q R S T U V W X Y Z~~

~~X Y Z W V U T S R Q P O N M L K J H G F D B A~~

- initial

solution:- compare a, b & c. so compare first a, first b, second a, second b & so on.

Design:-

Step 1:- q_0 is the initial state. The R/w head scans the leftmost a, replaces a by x and moves to the right. TM enters q_1 .

Step 2:- on scanning the leftmost b, The R/w head replaces b by y and moves to the right. TM enters q_2 . and replaces next b by y and moves to the right. TM enters q_3 .

Step 3:- on scanning the leftmost c, the R/w head replaces c by z, and moves to the left. TM enters q_4 .

Step 4:- It will move left until it finds the x and then it will move right again and enter q_0 .

and repeat - step 1 to 4. and the process goes on until all strings are replaced by x, y & z.

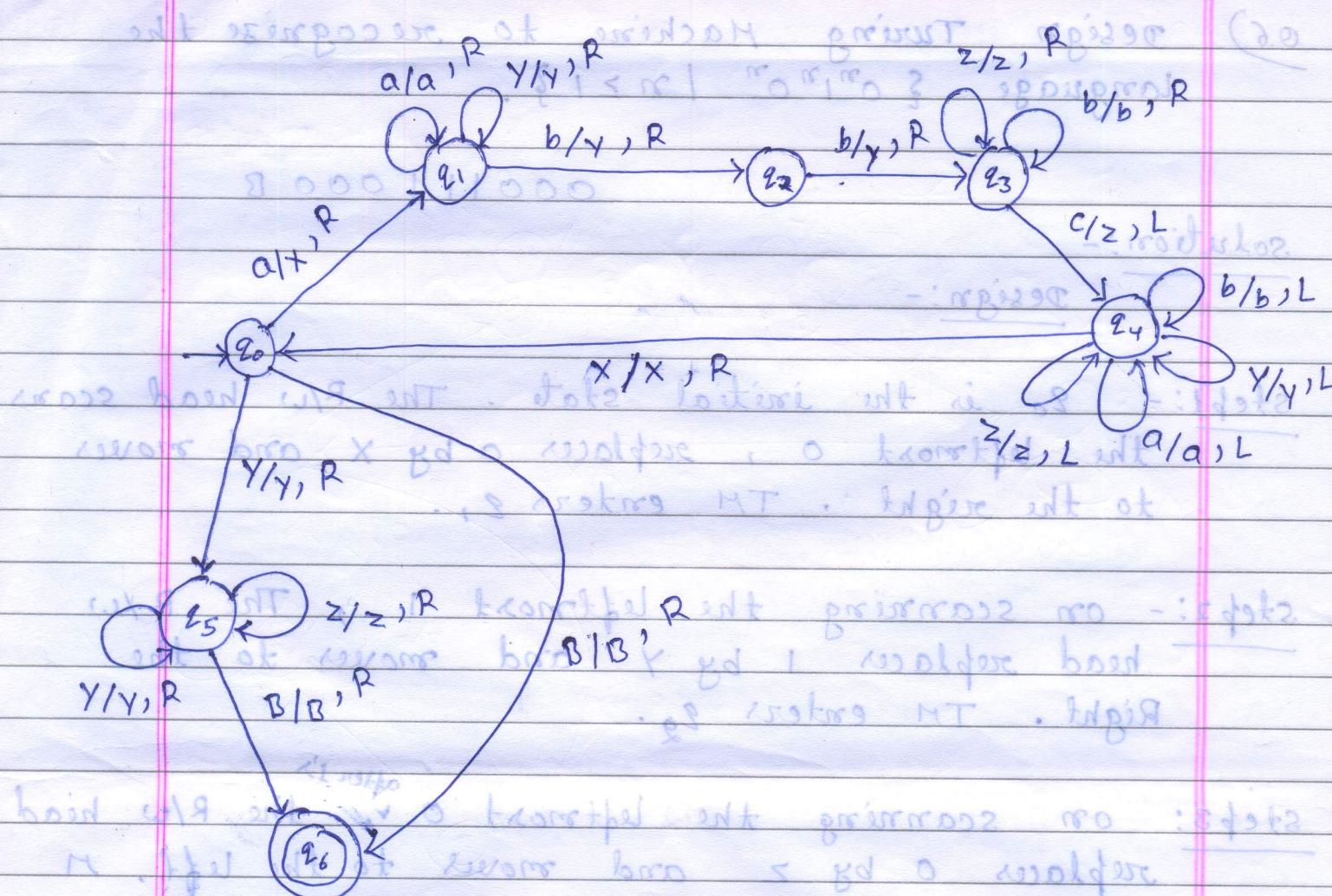
Step 5:- After replacing every string it finds blank, it will enter into final state.

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Tape symbol

Present State	a	b	c	x	y	z	B
$\rightarrow q_0$	(q_1, x, R)					(q_5, y, R)	(q_6, B, R)
q_1	(q_1, a, R)	(q_2, y, R)				(q_1, y, R)	
q_2		(q_3, y, R)					
q_3			(q_3, b, R)	(q_4, z, L)			(q_3, z, R)
q_4	(q_4, a, L)	(q_4, b, L)		(q_0, x, R)	(q_4, y, L)	(q_4, z, L)	
q_5					(q_5, y, R)	(q_5, z, R)	(q_6, B, R)
q_6							

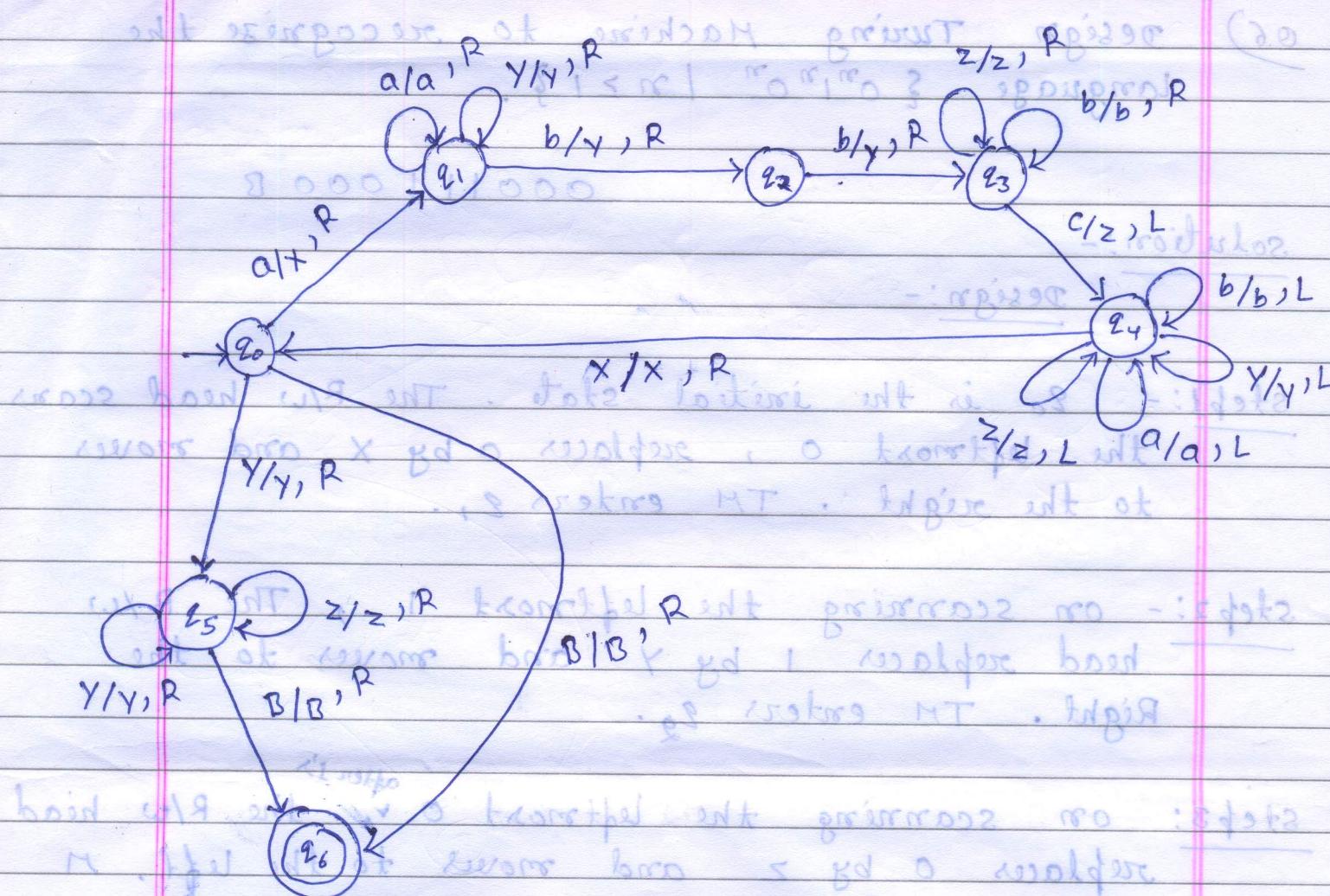
$$M = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6\}, \{a, b, c\}, \{a, b, c, x, y, z, B\}, S, q_0, B, \{q_6\})$$

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Tape symbol

Present State	a	b	c	x	y	z	B
$\xrightarrow{b/B} q_0$	(q_1, x, R)					(q_5, y, R)	(q_6, B, R)
q_1	(q_1, a, R)	(q_2, y, R)				(q_1, y, R)	
q_2		(q_3, y, R)					
q_3			(q_3, b, R)	(q_4, z, L)			(q_3, z, R)
q_4	(q_4, a, L)	(q_4, b, L)		(q_0, x, R)	(q_4, y, L)	(q_4, z, L)	
q_5					(q_5, y, R)	(q_5, z, R)	(q_6, B, R)
q_6							

$$M = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6\}, \{a, b, c\}, \{a, b, c, x, y, z, B\}, S, q_0, B, \{q_6\})$$

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Q6) Design Turing Machine to recognize the language $\{0^n 1^n 0^n \mid n \geq 1\}$.

solution:-

Design:-

Step 1:- q_0 is the initial state. The R/W head scans the leftmost 0, replaces 0 by X and moves to the right. TM enters q_1 .

Step 2:- on scanning the leftmost 1, the R/W head replaces 1 by Y and moves to the right. TM enters q_2 .

Step 3: on scanning the leftmost 0, the R/W head replaces 0 by Z and moves to the left. TM enters q_3 .

Step 4: it will move left until it finds the X and then it will move right again and enters q_4 .

and then repeat step 1 to 4. and the process goes on until all strings are replaced by X, Y, Z.

Step 5: After replacing every string it finds blank, it will enter into final state.

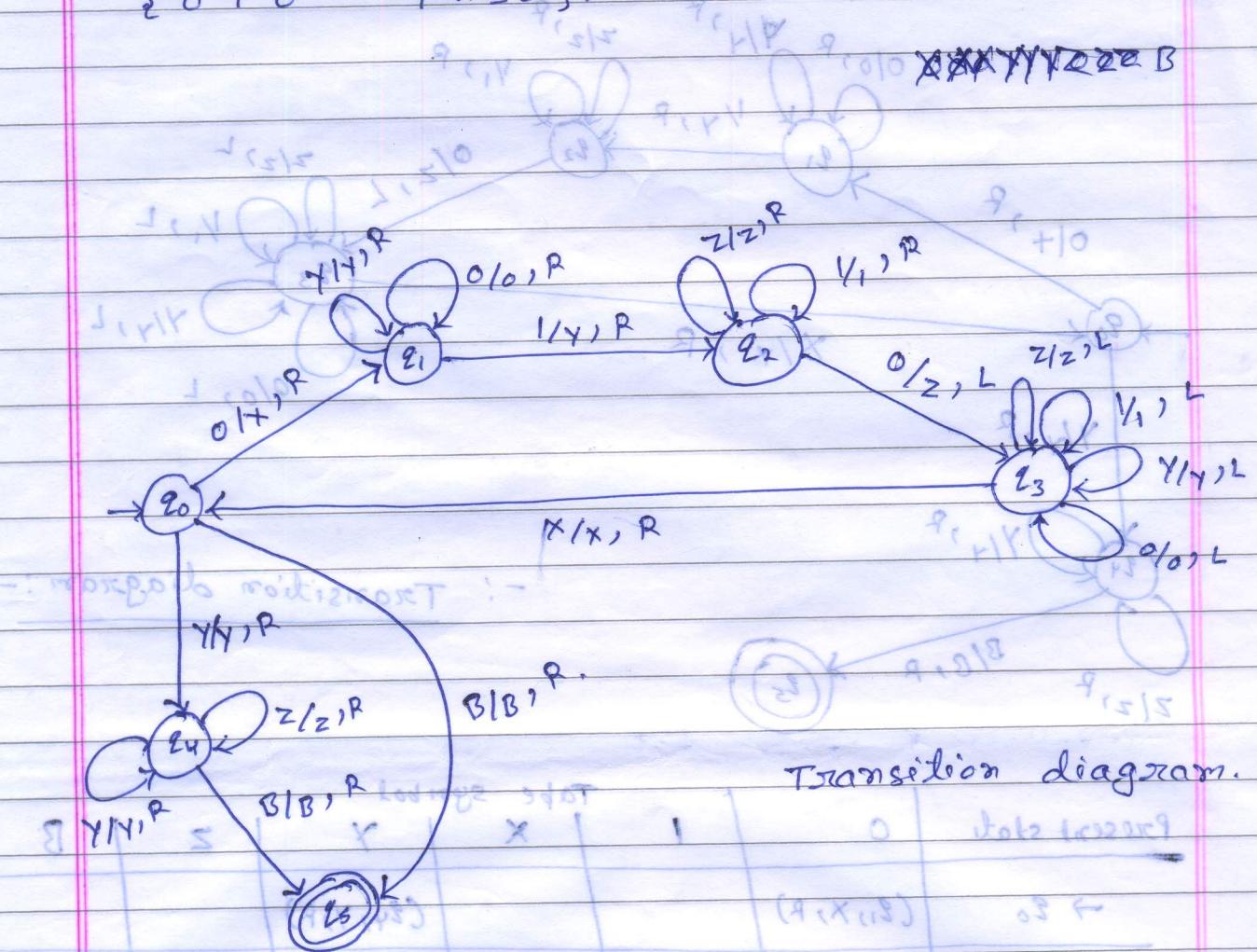
Question

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(Q7) Design Turing Machine to recognize the Language
 $\{0^n 1^n 0^n \mid n \geq 0\}$.



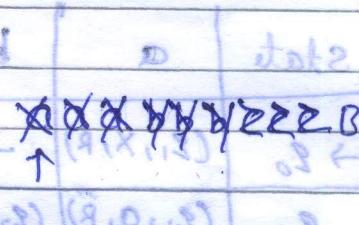
Present state	Tape symbol					Final state
	X	Y	Z	B		
$\rightarrow q_0$	(q_1, X, R)					(q_5, B, R)
q_1	$(q_1, 0, R)$	(q_2, Y, R)				
q_2	(q_3, Z, L)	$(q_2, 1, R)$				(q_2, Z, R)
q_3	$(q_3, 0, L)$	$(q_3, 1, L)$	(q_0, X, R)	(q_3, Y, L)	(q_3, Z, L)	
q_4	-	-	-	(q_4, Y, R)	(q_4, Z, R)	(q_5, B, R)
q_5	-	-	-	-	-	

$M = (\{q_0, q_1, q_2, q_3, q_4, q_5\}, \{0, 1, X, Y, Z, B\}, \delta, q_0, B, \{q_5\})$, δ is defined in transition

Q8) Design Turing Machine that recognizes the language: $\{ a^n b^n c^n \mid n \geq 1 \}$

Solution :-

Design: -



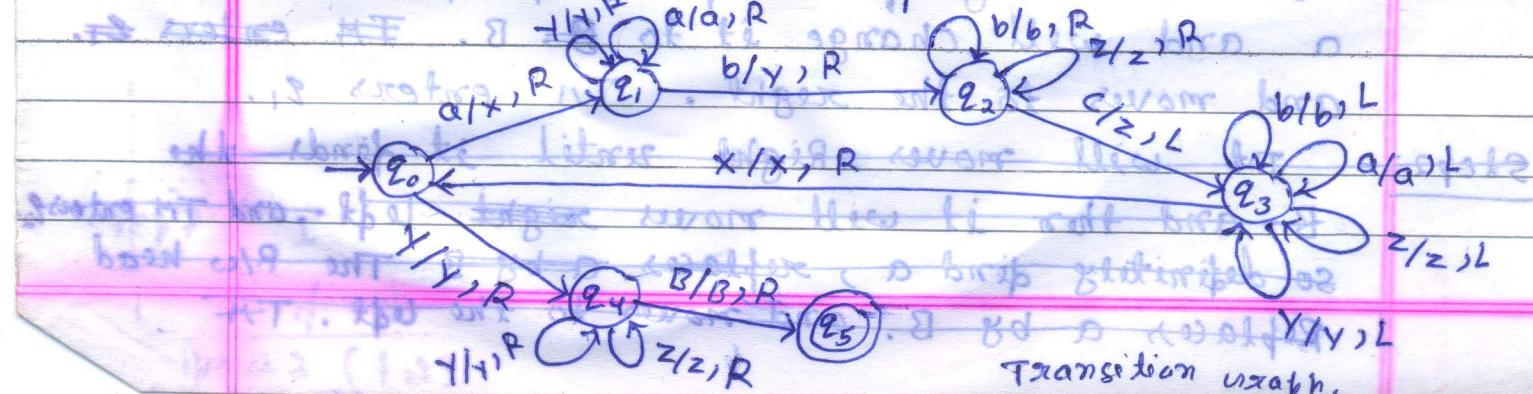
Step 1: q_0 is the initial state. The R/w head scans the leftmost a , Replaces a by x and moves to the Right. TM enters q_1 .

Step 2: - on scanning the leftmost 'b', The R/w head replaces 'b' by 'y' and moves to the right. TM enters q_2 .

Step 3: - On scanning the leftmost C, the R/W head replaces C by Z and moves to the left.
Hence the resultant string is ZZZ.

Step 4: It will move left until it finds the x and then it will move right again and enters the string, then repeat step 1 to 4, and the process goes on until all strings are replaced by x, y, z.

Step 5: After replacing every string in it find blank, here it will enter into final state.



Transition Table is given below (20)

State	a	b	c	x	y	z	B
$\rightarrow q_0$	(q_1, X, R)	-	-	-	(q_4, Y, R)	-	-
q_1	(q_1, a, R)	(q_2, Y, R)	-	-	(q_4, Y, R)	-	-
q_2	-	(q_2, b, R)	(q_3, Z, L)	-	-	(q_2, Z, R)	-
q_3	(q_3, a, L)	(q_3, b, L)	-	(q_0, X, R)	(q_3, Y, L)	(q_3, Z, L)	-
q_4	-	-	-	-	(q_4, Y, R)	(q_4, Z, R)	(q_5, B, R)
q_5	-	-	-	-	-	-	-

Turing Machine, M is defined as - $X \xrightarrow{y} d$ and $d \xrightarrow{z} B$

$$M = (\{q_0, q_1, q_2, q_3, q_4, q_5\}, \{a, b, c\}, \{a, b, c, x, y, z, B\}, \delta,$$

$$(q_0, B, \{q_5\})$$

δ is defined in Transition Table along M

Design Turing Machine to recognize the language $L = \{ww^R \mid w \in \{a, b\}^*\}$

Solution: - $L = \overbrace{ww^R}^{w \text{ of } 1 \text{ state longer than } w}$

Design: - w^R is the reverse of w. so

most symbol

Step 1: q_0 is the initial state. The R/W head starts scanning from left to right. It will read a and will change it to $B = B$. It enters q_1 and moves to the right. TM enters q_1 .

Step 2: It will move right until it finds the B and then it will move left and TM enters q_2 so definitely find a, replace a by B. The R/W head replaces a by B and moves to the left. TM enters q_3

~~Step 2:~~ It will move right until it finds the B. and then it will move left and TM enters q_2 .

~~Step 3:~~ so definitely find a, The R/w head Replaces a by B, and move to the left. TM enters q_3 .

~~Step 3:~~ It will move left until it finds the B, then it will move Right. TM enters q_0 .

If again reading a then Repeat step 1 to 3.
If reading b then Repeat step 4 to 6.

~~Step 4:~~ q_0 is the initial stat. if TM will read b and will change it to B. and moves to the right. TM enters q_4 .

~~Step 5:~~ It will move right until it finds the B. and then it (will) moves left and TM enters q_5 .

so definitely find b ; The R/w head Replaces b by B, and moves to the left. TM enters q_5 .

~~Step 6:~~ It ~~move~~ will move left until it finds the B, then it will move Right. TM enters q_0 .

If again reading b then repeat step 4 to 6.
If reading a then repeat step 1 to 3.

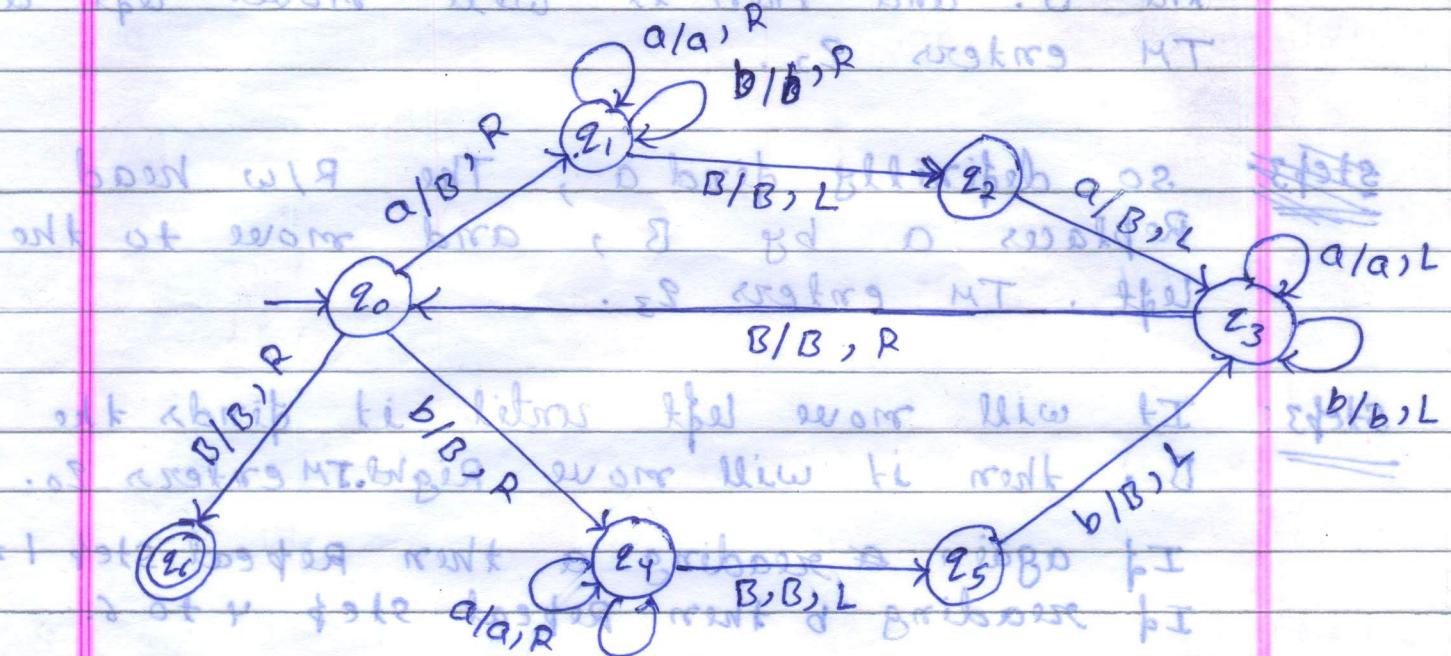
~~Step 7:~~ If I find Blank on q_0 . It enter into final state.

20

babbbaaa B
W R

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shripti letters engine seven new TI
birds spell seven new to next birds. It ent



out shrifti letters spell seven new TI
birds spell seven new to next birds. It ent

. So I got 7 states rank 2 above
20 r take a/a, R and B/B, R because PI

above new MT i.e. take looking out in of writing
of seven birds. It at the seventh new birds d

Transition Table of MT - Engine with

State	a	b	w	b	new	TI
MT \rightarrow Q0	(Q1, B, R)	(Q4, B, R)	(Q5, B, R)			
Q1	(Q1, a, R)	(Q1, b, R)	(Q2, B, L)			
Q2			(Q3, B, L)			
Q3			(Q3, B, L)			
Q4	(Q4, a, R)	(Q4, b, R)	(Q5, B, L)			
Q5		(Q3, B, L)				
MT \rightarrow Q6						

The Turing Machine is defined base rings PI

. So I got 7 states rank 2 because PI

MF = {Q0, Q1, Q2, Q3, Q4, Q5, Q6}, {a, b}, {a, b, B}, S, Q0, B, {Q6}

S is defined in Transition Table.

(21)

classmate

stop
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(10) Design Turing Machine to recognize the language $wLw = \{ww^R, \text{ where } w \in (a+b)^*\}$

Solution:-

Int. descrip to design - w^R is the reverse of w .

• MT has two ways to start from S

Step 1: q_0 is the initial state. If reading first head from left, if TM will read a and will change it to B and moves to the right. TM enters q_1 . 8 creating MT

Step 2: It will move right until it finds C and then it will again it will move right. TM enters q_2 . 8

Step 3: It will move right until it finds the B and then it will moves left and TM enters q_3 . 8

Step 4: So definitely find a, The R/W head replaces a by B, and move to the left. TM enters q_4 . 8 creating MT

Step 4: It will moves left until it finds the B, then it will move Right. TM enters q_0 . 8

If again reading a then Repeat step 1 to 4.

If reading b then Repeat step 5 to 8.

Step 5: q_0 is the initial state. Reading first from left. if TM will read b and will change it to B. and move to the Right. TM enters q_5 . 8



(15)

(22)



Step 6: If it will move right until it finds C (010) and then again it will move right. TM enters 26.

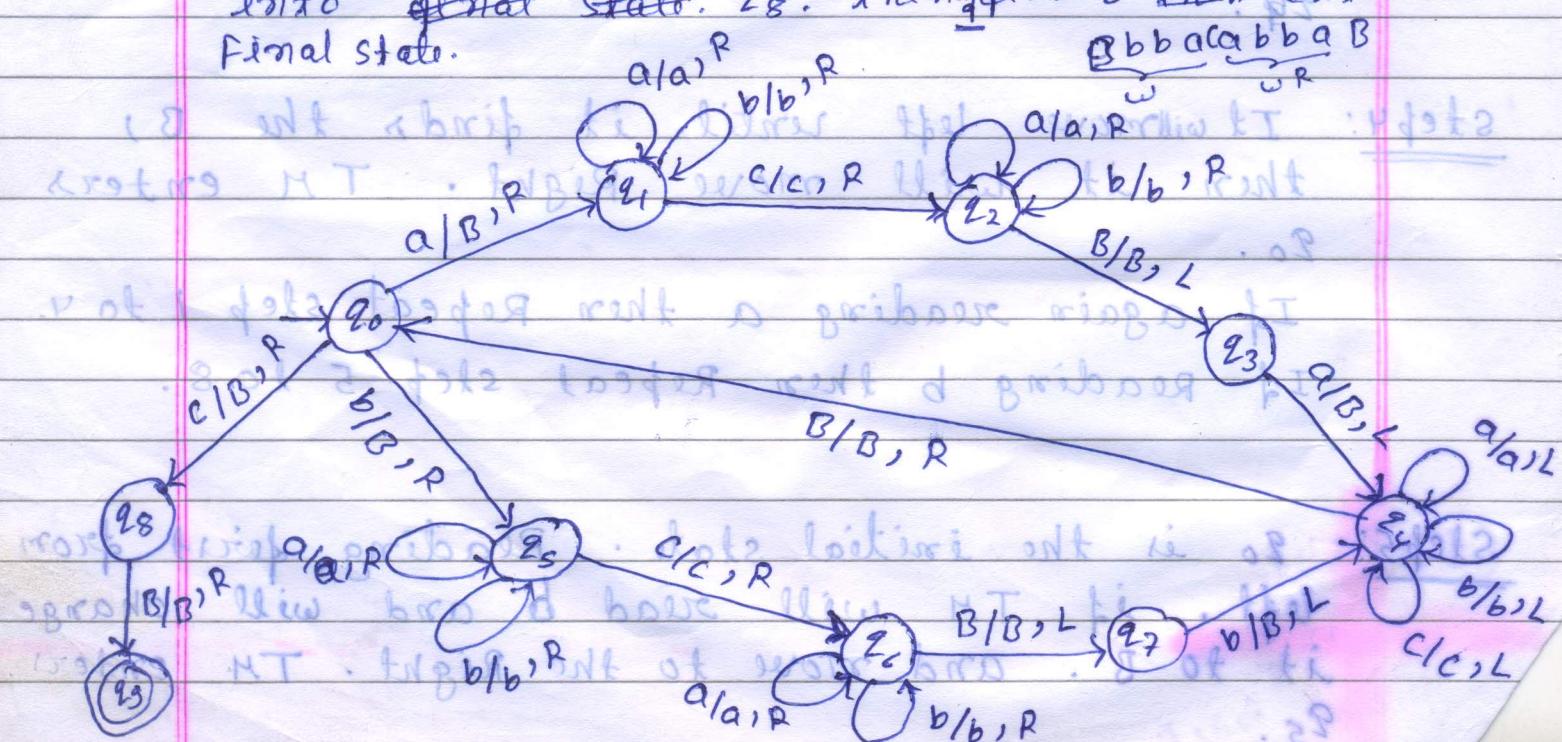
- : writing 010

Step 7: It will move right - until it finds the B and then it will move left and TM enters 27. So here definitely finds b, The R/b head replaces b by B, and move to the left. TM enters 28.

Step 8. If it moves left until it finds the B, then it will move right. TM enters 20.

If it again reads b then Repeat step 5 to creating MT bns. If it reads a then repeat step 1 to 4.

Step 9: If it finds blank on 20. It enters into final state. 28. Then if find B then enter into final state.



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Transition Table:-

state	a	b	c	B
$q_0 \rightarrow q_1$	(q_1, B, R)	(q_5, B, R)	(q_8, B, R)	-
q_1	(q_1, a, R)	(q_1, b, R)	(q_2, c, R)	-
q_2	(q_2, a, R)	(q_2, b, R)	-	(q_3, B, L)
q_3	(q_4, B, L)	-	-	-
q_4	(q_4, a, L)	(q_4, b, L)	(q_4, c, L)	(q_0, B, R)
q_5	(q_5, a, R)	(q_5, b, R)	(q_6, c, R)	-
q_6	(q_6, a, R)	(q_6, b, R)	-	(q_7, B, L)
q_7	-	(q_4, B, L)	-	-
q_8	-	-	-	(q_9, B, R)
q_9	-	-	-	-

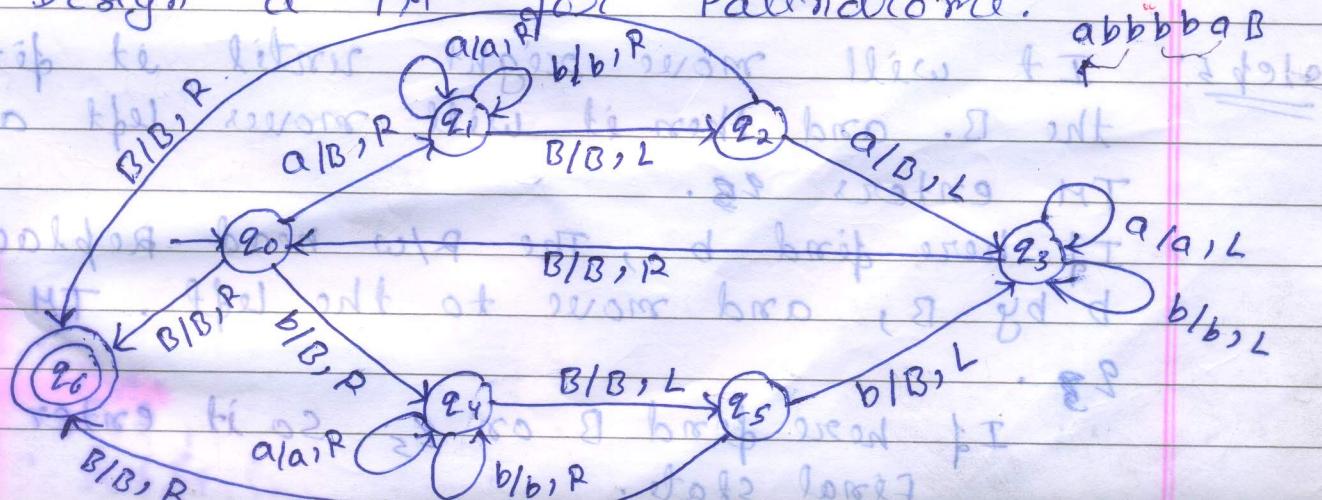
Turing Machine M is defined as:-

$$M = (Q, \{a, b, c\}, \{a, b, c, B\}, \delta, q_0, B, \{q_9\})$$

$$\delta = \{(q_0, a, R, q_1), (q_0, b, R, q_5), (q_0, c, R, q_8), (q_1, a, R, q_1), (q_1, b, R, q_1), (q_1, c, R, q_2), (q_1, B, R, q_5), (q_2, a, R, q_2), (q_2, b, R, q_2), (q_2, c, R, q_3), (q_2, B, R, q_8), (q_3, a, R, q_3), (q_3, b, R, q_3), (q_3, B, L, q_0), (q_4, a, L, q_4), (q_4, b, L, q_4), (q_4, c, L, q_4), (q_4, B, L, q_1), (q_5, a, R, q_5), (q_5, b, R, q_5), (q_5, c, R, q_6), (q_5, B, R, q_1), (q_6, a, R, q_6), (q_6, b, R, q_6), (q_6, c, R, q_7), (q_6, B, R, q_5), (q_7, a, R, q_7), (q_7, b, R, q_7), (q_7, B, L, q_4), (q_8, a, L, q_8), (q_8, b, L, q_8), (q_8, c, L, q_8), (q_8, B, L, q_2), (q_9, B, R, q_9)\}$$

δ is defined in Transition Table.

(ii) Design a TM for Palindrome.





step1: q_0 is the initial state. Reading first from left. If TM will read a and will change it to B. and moves to the right. TM enters q_1 .

step2: It will move right until it finds the B. and then it will moves left and TM enters q_2 .

If so ~~definitely~~ find a, The R/w head replaces a by B, and move to the left. TM enters.

on q_2 , If here find B on q_2 so it enter into final state.

step3: It will on q_3 , It will move left until it finds the B, then it will move right. TM enters q_0 .

If again reading a then repeat step 1 to 3.
If reading b then repeat step 4 to 6. = M

step4: q_0 is the initial state. if TM will read b and will change it to B. and moves to the right. TM enters q_4 .

step5: It will move right until it finds the B. and then it will moves left and TM enters q_5 .

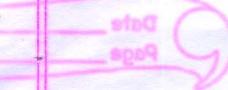
If here find b, The R/w head replaces b by B, and move to the left. TM enters

q_6 .

If here find B on q_5 so it enter into final state.



states



Step 6: (on q_3), If it will move left until it finds 'a' in the B , then it will move right if it enters q_0 .

$$\{a\} = \{a\}$$

on q_0 , If again reading 'a' then repeat step 1 to 3.

q_0

MT obrí struktur start gríwolot bavros

on q_0 , If reading 'b' then repeat step 4 to 6.

Step 7: If find blank on q_0 . It enters into final state.

The Turing Machine M is defined as:-

$$M = (\{q_0, q_1, q_2, q_3, q_4, q_5, q_6\}, \{a, b\}, \{a, b, B\}, S, q_0, B, q_6)$$

start struktur

S is defined as:-

-: initial

$$S(q_0, a) = (q_1, B, R)$$

$$S(q_0, b) = (q_4, B, R)$$

$$S(q_0, B) = (q_6, B, R)$$

$$S(q_1, a) = (q_1, a, R)$$

$$S(q_1, b) = (q_1, b, R)$$

$$S(q_1, B) = (q_2, B, L)$$

$$S(q_2, a) = (q_3, B, L)$$

$$S(q_2, B) = (q_6, B, R)$$

$$S(q_3, a) = (q_3, a, L)$$

$$S(q_3, b) = (q_3, b, L)$$

$$S(q_3, B) = (q_0, B, R)$$

$$S(q_4, a) = (q_4, a, R)$$

$$S(q_4, b) = (q_4, b, R)$$

$$S(q_4, B) = (q_5, B, L)$$

$$S(q_5, a) = (q_3, B, L)$$

$$S(q_5, B) = (q_6, B, R)$$

-: beripek u 3

$$(q_0, 0, 000) = (0, 000) 2$$

$$(q_1, 0, 000) = (1, 000) 2$$

$$(q_0, 0, 000) = (0, 000) 2$$

$$(q_1, 1, 000) = (1, 000) 2$$

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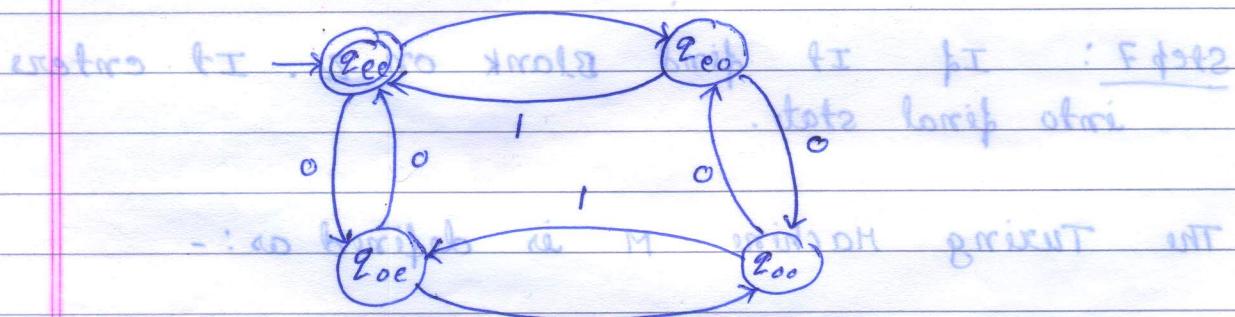
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(Q12) Construct a NFA for the languages of even number of 1's and even number of 0's over $\Sigma = \{0, 1\}$.

gotz longer until 'n' gribous rings + I, as well
ox

convert Following Finite automata into TM.

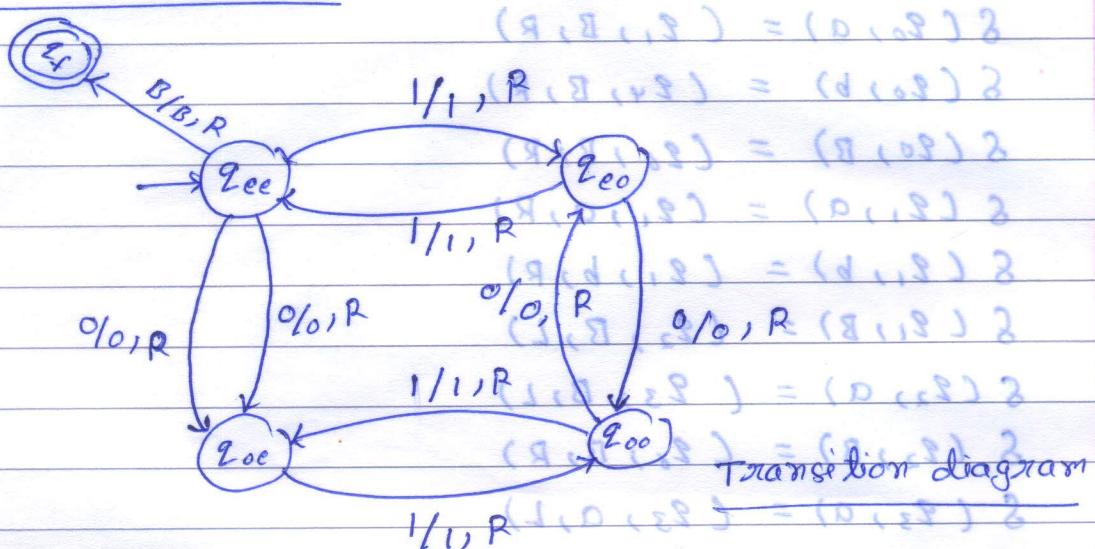
at y dts tds mlt 'd' gribore fI i.2 no



$(S, \Sigma, \delta, s_0, f)$ is a finite automata.

Solution:-

convert into TM :-



Turing Machine $M = (\{q_0, q_1, q_2, q_{00}, q_{01}, q_f\}, \{0, 1\}, \{0, 1, B\}, \delta, q_0, B; q_f)$.

S is defined :-

$$S(\varrho_{ee}, 0) = (\varrho_{oe}, 0, R)$$

$$\delta(\mathcal{Q}_{ee}, 1) = (\mathcal{Q}_{eo}, 1, R)$$

$$\delta(Q_{ee}, 0) = (Q_{ee}, 0, R)$$

$$\delta(\varrho_{00}, \mathbf{r}) = (\varrho_{00}, \mathbf{t}, \mathbf{R}).$$

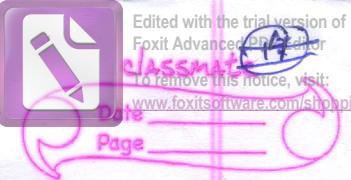
$$S(q_{\text{eq}}, 0) = (q_0, 0, R)$$

$$\delta(2_{\text{FO}}, 1) = (2_{\text{FO}}, 1, \mathbb{R})$$

$$(\varphi_{\alpha}, 0) = (\varphi_{\alpha}, 0, R)$$

$$f(2001) = (g_{2001}, \mathbb{R})$$

$$g((z_0, \beta), R) = (g_1, \beta, R)$$



(Q8) Construct a TM (for $L = \{a^m b^n\}$ language) having equal number of 'a's and 'b's in it over the input set $\Sigma = \{a, b\}$. (Two-way infinite Tape) $(q_1, q_2) = (q_3, q_4) 2$

Solution: Here we will clearly stated the advantage of infinite two ends of the input tape. $(q_1, q_2) = (q_3, q_4) 2$

$$B, b, a, a, b, b, b, a, a, B = (q_1, q_2) 2$$

\downarrow $(q_1, q_2) = (q_3, q_4) 2$

We will have a simple logic (as if we get 'a'). We will replace it by x and move right in search of 'b', if we get 'b' we will replace it by y and move left. $(q_1, q_2) = (q_3, q_4) 2$

$$(q_1, q_2) = (q_3, q_4) 2$$

If we get 'b'. We will replace it by y and move right in search of 'a', if we get 'a' we will replace it by x and move left. $(q_1, q_2) = (q_3, q_4) 2$

Now repeat these processes.

$$(q_1, q_2) = (q_3, q_4) 2$$

$$(q_1, q_2) = (q_3$$



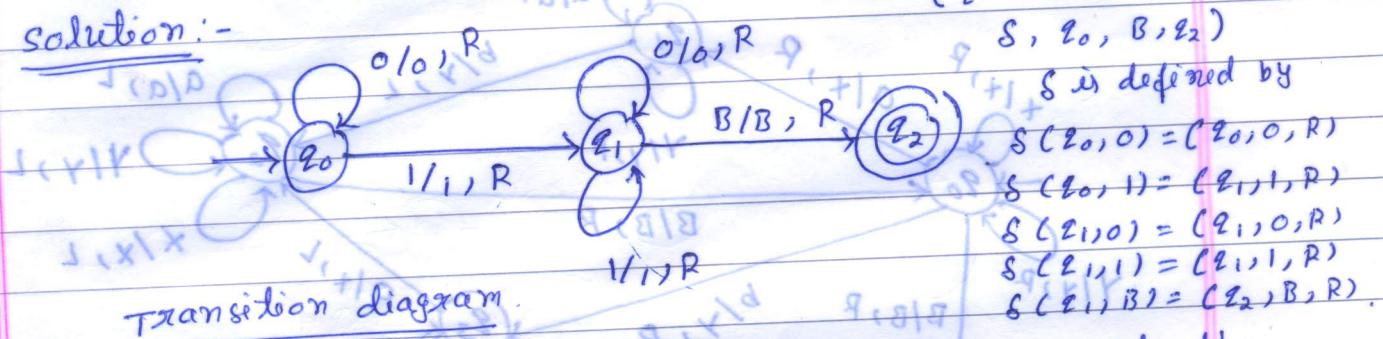
F2

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- $S(2_0, a) = (2_1, X, R)$ MT D turing
 heki $S(2_0, X) = (2_0, X, R)$ D p radhe
 (MT) $S(2_0, b) = (2_3, Y, R)$ $\{d, D\} \Rightarrow b_0$
 $S(2_0, Y) = (2_0, Y, R)$
 S(2_0, B) = (2_4, B, R) $\{a, A\} \Rightarrow$
 S(2_0, a) = (2_1, a, R) $\{b, B\} \Rightarrow$
 $S(2_1, b) = (2_2, Y, L)$ spot turing
 $S(2_1, Y) = (2_1, Y, R)$ d R
 $S(2_1, a) = (2_2, a, L)$ ↑
 $S(2_2, X) = (2_2, X, L)$ a word New sw
 $S(2_2, Y) = (2_2, Y, L)$ ti valde New sw
 $S(2_2, B) = (2_0, B, R)$ fi 'd' p n25028
 $S(2_3, a) = (2_2, X, L)$ pi warr hro Y yd
 $S(2_3, b) = (2_3, b, R)$
 $S(2_3, X) = (2_3, X, R)$ 'd' kag sw ft
 $'d'$ p n25028 fi 'd' p n25028 in tigre swom

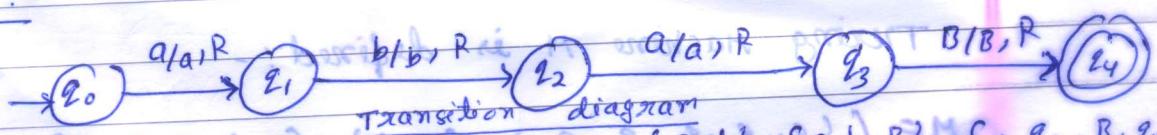
(a) Design a Turing machine that recognizes the set of all strings of 0's and 1's containing at least one 1.

Solution:-



(b) Construct a Turing machine which accept the language of abab over $\Sigma = \{a, b\}$.

Solution:-



Turing Machine $M = \{2_0, 2_1, 2_2, 2_3, 2_4, \{a, b\}, \{a, b\}, \{a, b\}, \{B\}, S, 2_0, B, 2_4\}$.

$S \text{ is defined by}$

$S(2_0, a) = (2_1, a, R)$	$S(2_2, a) = (2_3, a, R)$
$S(2_1, b) = (2_2, b, R)$	$S(2_3, B) = (2_4, B, R)$



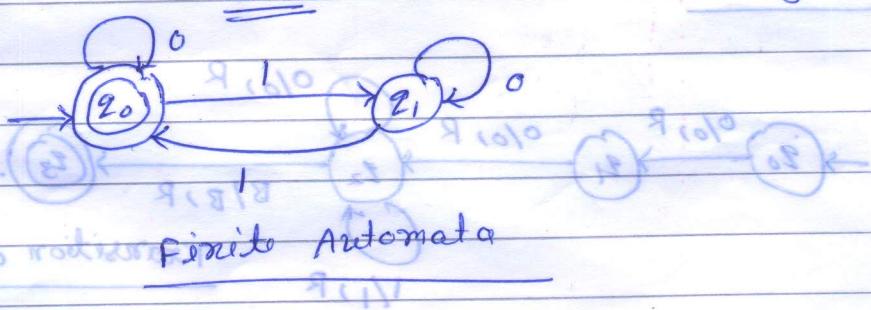
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FA and Turing Machine: -

- Q16) construct TM for languages consisting of strings having any number of '0's and only even number of '+1's over the input set $\Sigma = \{0, 1\}$. (10)

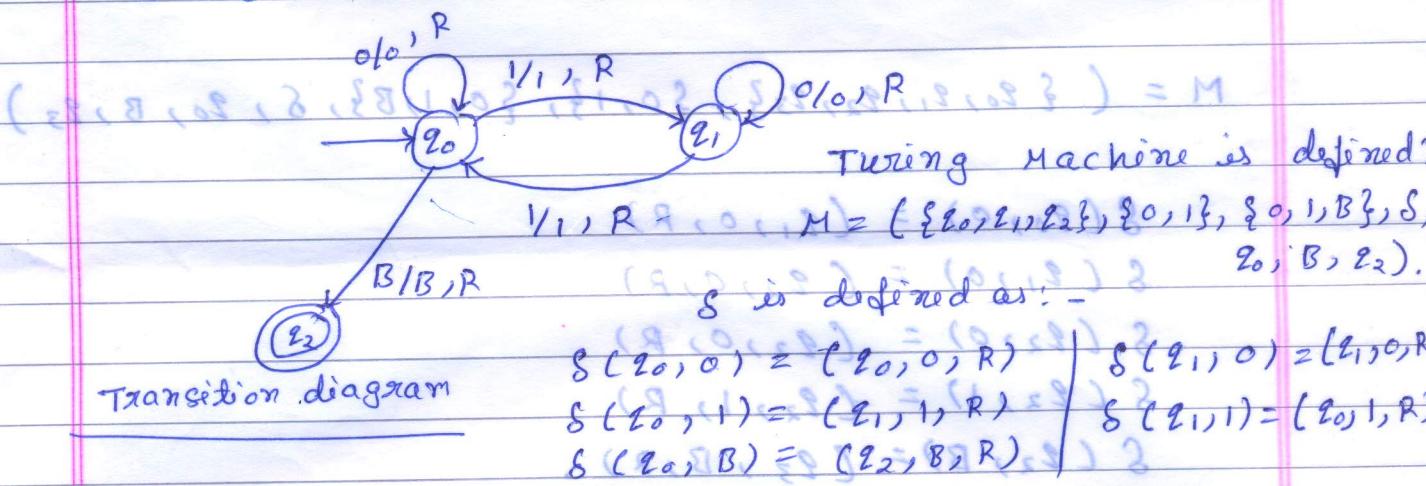
convert following FA to TM.



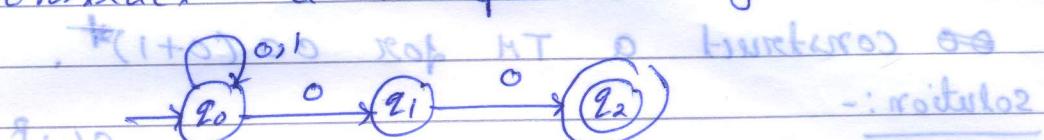
Solution:

- :- as described in M written below

convert into Turing Machine: -

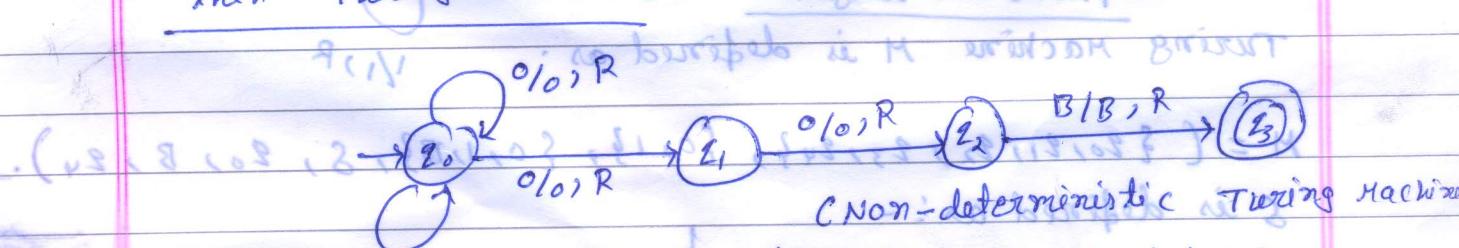


- Q17) construct a TM for the given FA.



Solution: -

then Turing Machine: -



so Turing Machine: M =

$$M = \{q_0, q_1, q_2, q_3\}, \{0, 1\}, \{q_0, 1, B\}, S, q_2, q_3\}$$

δ is defined as: -

$$\begin{array}{l|l} \delta(q_0, 0) = \{q_1, 0, R\}, & \delta(q_1, 0) = \\ \delta(q_0, 1) = \{q_2, 1, R\}, & \delta(q_1, 1) = \\ \delta(q_2, 0) = \{q_1, 0, R\}, & \delta(q_2, 1) = \\ \delta(q_2, 1) = \{q_3, B, R\}. & \end{array}$$



Q30 : urwindm present bno A7

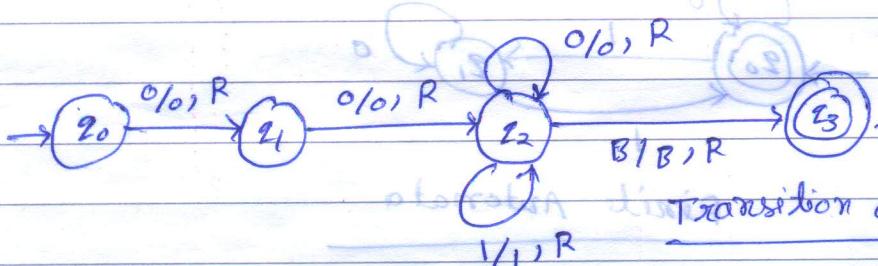


Practical conversion of RE to Turing TM : MT functions (10)

rows bno bno & p seadur yord givval

(Q1) construct a TM for $0^*0(0+1)^*$

MT of solutions functions



Transition diagram.

Turing Machine M is defined as:-

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

: bno bno in urwindm givval

$$\delta(q_0, 0) = (q_1, 0, R)$$

$$\delta(q_1, 0) = (q_2, 0, R)$$

$$\delta(q_2, 0) = (q_2, 0, R)$$

$$\delta(q_2, 1) = (q_2, 1, R)$$

$$\delta(q_2, B) = (q_3, B, R)$$

A7 rearing ont rof MT n functions

(Q2) construct a TM for $0^*0(0+1)^*$.

solution:-



Transition diagram

Turing Machine M is defined as:-

$$M = (\{q_0, q_1, q_2, q_3, q_4\}, \{0, 1\}, \{0, 1, B\}, \delta, q_0, B, q_4).$$

s is defined as:-

$$\delta(q_0, 0) = (q_1, 0, R) \quad \delta(q_3, 0) = (q_3, 0, R)$$

$$\delta(q_1, 0) = (q_2, 0, R)$$

$$\delta(q_2, 0) = (q_3, 0, R)$$

$$\delta(q_2, 1) = (q_3, 1, R)$$

$$\delta(q_3, 1) = (q_3, 1, R)$$

$$\delta(q_3, B) = (q_4, B, R)$$

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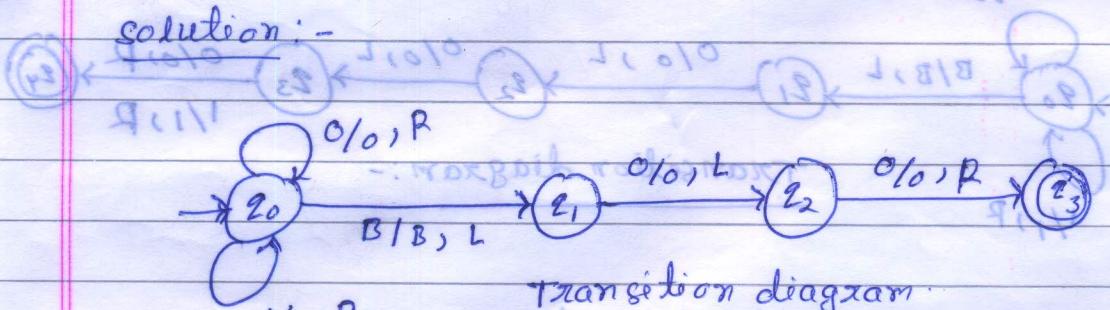
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* check from back to segment (structure) (20) - read all

(Q1) construct TM for $(0+1)^* 00B$

solution:-



so Turing Machine $M = (\{q_0, q_1, q_2, q_3\}, \{0, 1, B\}, \delta, (q_0, 0, R), (q_0, 1, R), (q_0, B, L), (q_1, 0, L), (q_2, 0, R), (q_3, 1, R))$.

δ is defined:-

- : gd berifab in 2 seasko

$$\delta(q_0, 0) = (q_0, 0, R)(q_0, 0, R) = (0, 0, R)$$

$$\delta(q_0, 1) = (q_0, 1, R)(q_0, 1, R) = (1, 1, R)$$

$$\delta(q_0, B) = (q_1, B, L)(q_1, B, L) = (B, B, L)$$

$$\delta(q_1, 0) = (q_2, 0, L)(q_1, 0, L) = (0, 0, L)$$

$$\delta(q_2, 0) = (q_3, 0, R)(q_2, 0, R) = (0, 0, R)$$

$$(q_0, 0, R) = (0, 0, R)$$

Procedure:

$(0+1)^* 00B$ (Read all 0's & 1's on

\uparrow
 q_0)

$\cdot (1, 0, 3) = 3$ word w * 00 q_0 of MT o tukturor (20)

$(0+1)^* 00B$ (then back from blank)

\uparrow
 q_0

$\cdot (0+1)^* 00B$ (Read one zero from back)

\uparrow
 q_1

$(0+1)^* 00B$ (Read second zero from back)

\uparrow
 q_2

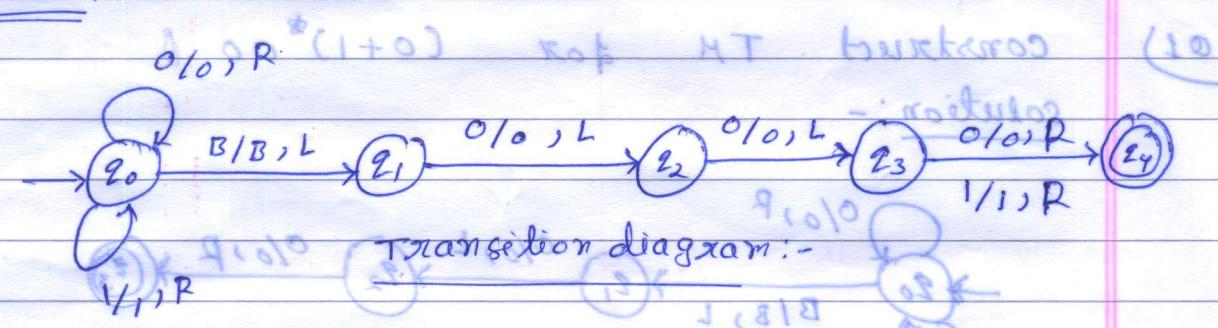
$(1, 0, 3) = (0, 0, 3)$

$(q_0, 0, R) = (0, 0, R)$

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Q2). Construct Turing Machine for $(0+1)^* 00^*$.

Solution:-



Turing Machine M is defined by:-

$$\begin{aligned} & \delta(\{0, 1\}^*, \{0, 1\}^*, \{0, 1\}^*) = M \text{ transition function } \delta \\ & \delta(M) = (\{q_0, q_1, q_2, q_3, q_4\}, \{0, 1\}, \{0, 1, B\}, \delta, q_0, B, q_4). \end{aligned}$$

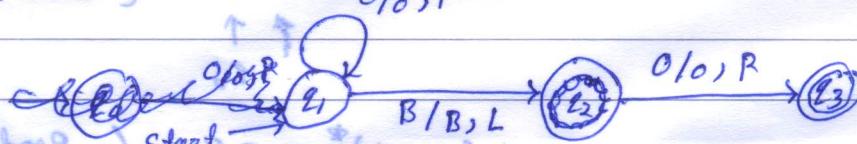
where δ is defined by:-

$$\begin{aligned} \delta(q_0, 0) &= (q_0, 0, R) (q_0, 0, 0) = (0, 0) 2 \\ \delta(q_0, 1) &= (q_0, 1, R) (q_0, 1, 0) = (1, 0) 2 \\ \delta(q_0, B) &= (q_1, B, L) (q_0, B, 0) = (B, 0) 2 \\ \delta(q_1, 0) &= (q_2, 0, L) (q_1, 0, 0) = (0, 1) 2 \\ \delta(q_2, 0) &= (q_3, 0, L) (q_2, 0, 0) = (0, 0) 2 \\ \delta(q_3, 0) &= (q_4, 0, R) \\ \delta(q_3, 1) &= (q_4, 0, R) \end{aligned}$$

Q3) construct a TM for $00^* 00^*$ where $\Sigma = \{0, 1\}$.

Solution:-

$$00^* 00^* (0/0, R)$$



Transition diagram:-

Turing Machine $M = (\{q_0, q_1, q_2, q_3\}, \{0, 1\}, \{0, 1, B\}, \delta, q_0, B, q_3)$.

δ is defined by:-

$$\delta(q_0, 0) = (q_1, 0, R)$$

$$\delta(q_1, B) = (q_2, B, L)$$

$$\delta(q_2, 0) = (q_3, 0, R)$$



Turing Machine as computable Functions:-

A Turing Machine is a language acceptor which checks whether a string is accepted by being in a language it takes input from & outputs to tape.

In addition to that it may be viewed as a computer which performs computations of functions from '0' to numbers to integers.

(a) Design a Turing Machine that computes $m+n$ for the given two positive integers m, n .

The solution will be as follows:

Let the number is unary. We know that unary number is made up of only one character (Assume '0').

For Example 5 can be written in unary number system as '00000'.

So assume m & n are two numbers in every unary notation separated by single '1'.

00000 1 000 B
m n

So construct a TM to perform addition of two unary numbers.

Design concept: (i) The separating symbol '1' is found and replaced by '0'.

(ii) The rightmost '0' is found and replaced by blank(B).



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So ~~Turing~~ Turing Machine is defined by :-

$$M = (\{z_0, z_1, z_2, z_3\}, \{0, 1\}, \{0, 1, B\}, S, z_0, B, \{z_3\}).$$

S is defined in Transition Table.

at 02) Design a Turing machine over $\{1, b\}$ which
leads to w^q ~~not~~ compute a concatenation function over $\Sigma = \{1\}$.

If a pair of words (w_1, w_2) is the input, the output has to be $w_1 w_2$.

assume that the two written initially on the symbol b .

Solution :

Let us assume that the two words w_1 and w_2 are written initially on the input tape separated by the symbol b .

for example, if $w_1 = 11$, $w_2 = 111$, then the input and output tapes.



$$(w_1, w_2) \in \{1, 2, 3\}^2$$

Input and output tapes.

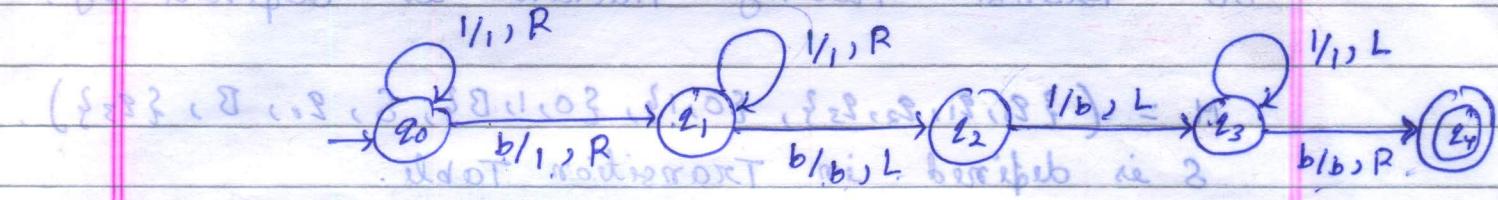
We observed that the main task is to remove the symbol T_b . This can be done in the following manner:-

- (i) The separating symbol ; is found and replaced by $,$.
(ii) The rightmost 1 is found and replaced by blank b.

Result (iii) The R/wa head returns to the starting position.

Significant here is a 3rd derivative of a step function with respect to

- : M describes in position greatest TMR



Now Ed. 1.3. ~~in~~ Transitions diagram: - D. where we want to

$f_1 = \text{zero return code to start}$ $f_2 = \text{return R/w at start}$

Transition Table: $(q_i, w) \rightarrow q_j$ if $f_i(w, q_j)$

w, q_j cd of and return with

state	1	b	
$\rightarrow q_0$	$(q_0, 1, R)$	$(q_1, 1, R)$: initial
q_1	$(q_1, 1, R)$	(q_2, b, L)	on 1
q_2	(q_3, b, L)		on 0 return
q_3	$(q_3, 1, L)$	(q_4, b, R)	on 1
q_4			on 0 return

so Turing Machine defined by :-

$\{0, 1\}^*$ $\{0, 1\}^*$

$$M = \{ \{q_0, q_1, q_2, q_3, q_4\}, \{1, b\}, S, \delta, q_0, b, \{q_4\} \}.$$

at last bro tape

Q3) Proper subtraction m-n is to be defined between

Binary m > n is and zero for m < n. DT has no int

- : normal

Solution: started with $0^n 1^m$ on its tape,

1st blank us ~~both~~ halfs in with 0^{m-n} on its tape. (i)

1st Design concept bro tape is 1 to right give off (ii)

M repeatedly replaces its leading 0 by blank (iii) then searches right for a 1 followed by a 0 and changes the 0 to 1.

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Next, M moves left until it encounters a blank and then repeats the cycle.

$(\{0,1\}^n, \{0,1\}^n, \text{Start}, \{0,1\}^n, \{0,1\}^n, \{0,1\}^n, \dots) = M$

The repetition ends if m is 2

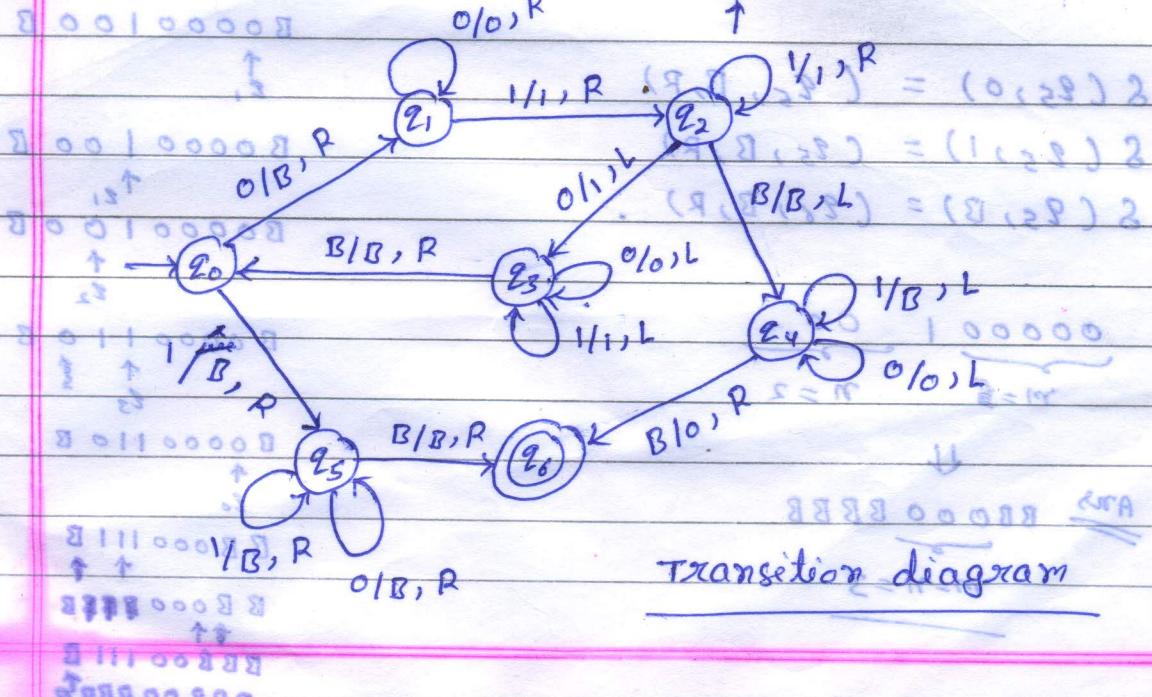
(i) Searching right for $0, 0$, M encounters a blank. Then, the $n - m + 1 = 0^m + 0^n$ have all been changed to 1's (and $m+1 = n$ other m o's have been changed to blanks) $= (1, 1)^n 2$

↓ ↓ ↓ So when M encounters a blank, we will move left & replace all 1's to blanks, until blank is found. then replace (one blank = to $0, 0$) and enter into final state. $(1, 1, \text{Final}) = (0, 0)^n 2$

(ii) Beginning the cycle, $(0, M)$ cannot find a '0' to change to a blank, because (the) first m 0's already have been changed. \Rightarrow (Then) $n \geq m$, so $m - n = 0$. M replaces all remaining 1's and 0's by Blank. $(1, 0, \text{Final}) = (0, 0)^n 2$

$(1, 0, \text{Final}) = (0, 0)^n 2$

$(1, 0, \text{Final}) = (0, 0)^n 2$



o M is defined by two sets M_1 and M_2 such that $M = M_1 \cup M_2$.

$$M = (\{z_0, z_1, z_2, z_3, z_4, z_5, z_6\}, \{0, 1\}, \{0, 1, B\}, S, z_0, B, \{z_6\}).$$

S is defined by :-

$$S(z_0, 0) = (z_1, B, R), \text{ logic principle (i)}$$

$$S(z_0, 1) = (z_5, B, R) \text{ at start position}$$

$$S(z_1, 0) = (z_1, 0, R) \text{ at begining}$$

$$S(z_1, 1) = (z_2, 1, R) \text{ at begining} \quad \boxed{B B B B B B B B B B B B}$$

Now we have a sequence of moves M which are $\downarrow \downarrow \downarrow$

$$S(z_2, 0) = (z_3, 1, L) \text{ before } \boxed{B B B B B B B B B B B B}$$

$$S(z_2, 1) = (z_2, 1, R) \text{ before next transition} \quad \uparrow$$

$$S(z_2, B) = (z_4, B, L) \quad \text{state } \boxed{B B B B B B B B B B B B}$$

$$S(z_3, 0) = (z_3, 0, L) \text{ at principle (ii)}$$

$$S(z_3, 1) = (z_3, 1, L) \text{ at begining}$$

$$S(z_3, B) = (z_5, B, R) \text{ at begining}$$

Now we have a sequence of moves M . $n = m - n = 0$

$$S(z_4, 0) = (z_4, 0, L) \quad \text{Procedure}$$

$$S(z_4, 1) = (z_4, B, L)$$

$$S(z_4, B) = (z_6, 0, R)$$

$\boxed{00000100B}$

\uparrow

$\boxed{B0000100B}$

\uparrow

$\boxed{B0000100B}$

$\boxed{B0000100B}$

$\boxed{B0000100B}$

\uparrow

$\boxed{B0000100B}$

\uparrow

$\boxed{B0000100B}$

\uparrow

$\boxed{B0000100B}$

\uparrow

$\boxed{B0000100B}$

\uparrow

$\boxed{B0000100B}$

\uparrow

$\boxed{BB0000BBBB}$

$m-n=3$

$m-n=3$

$m-n=3$

$m-n=3$

$m-n=3$

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(Q4) Construct a TM for the function $f(x) = x + 3$, if $x \geq 0$.
 $0 \leq x \leq 2 + n = (n)^2$

Solution:

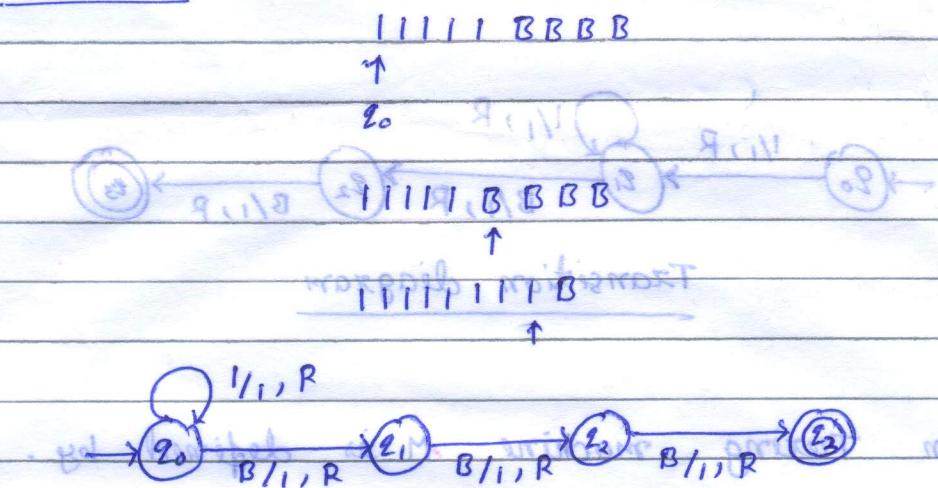
At first consider the TM which has to be constructed for unary number system sap. Assume input set $\Sigma = \{1\}$.
The logic is very simple. We first go to moving towards rightmost end of input string. Then replace three blank's to 1's and enter into final state.

To complete above problem of going to final state

at first we will write input - agree before 10

If $x = 11111 BBBB$ then $f(x) = 11111111 B$
 $x = 5$ $f(x) = 8$.

Procedure:



$(\Sigma, \Delta, \delta, q_0, q_f)$ = M
and briefs in 3 words

Then Turing machine M is defined by.

$$(\Sigma, \Delta, \delta) = (\{1, B\}, \{1, B\}, \delta)$$

$$M = (\{q_0, q_1, q_2, q_3\}, (\Sigma, \Delta, \delta), q_0, q_f)$$

where δ is defined by $\delta(s) = (\delta(s))$

$$\delta(q_0, 1) = (q_1, 1, R) \Rightarrow (\delta(q_0, 1)) = (q_1, 1, R)$$

$$\delta(q_1, 1) = (q_2, 1, R)$$

$$\delta(q_2, 1) = (q_3, 1, R)$$

$$\delta(q_3, 1) = (q_f, 1, R)$$

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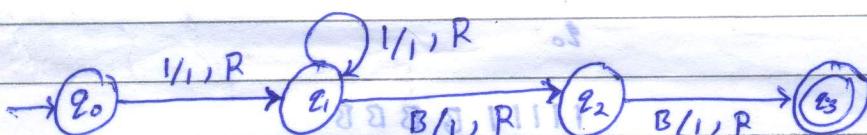
(Q5) construct Turing machine for the function
 $f(n) = n+2 \text{ if } n > 0.$

(P)

: modulo 2

solution: since the Turing machine has to be
 be built constructed for binary number system. we
 give our assignment set $\{1, 0\}$ given in input INT
 voltage and provide binary to binary conversion chart
 that the logicities very much simpler. since we
 we just going to moving towards rightmost end
 of input strings. Then replace two blank's to 1's
 and enter into final state. $1111 = \overbrace{\quad}^2 + \overbrace{\quad}^1$

$$\text{If } \underbrace{\text{1111 BBB}}_{n=4} \text{ then } \underbrace{\text{11111 B}}_{f(n)=69}$$



Transition diagram

Then Turing machine M is defined by.

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

where δ is defined by

$$\delta(q_0, 1) = (q_1, 1, R).$$

$$(\delta(q_1, 1) = (q_2, 1, R)) \cup (\delta(q_1, B) = (q_3, 1, R)) = M$$

$$\delta(q_1, B) = (q_3, 1, R) \text{ because it is final state}$$

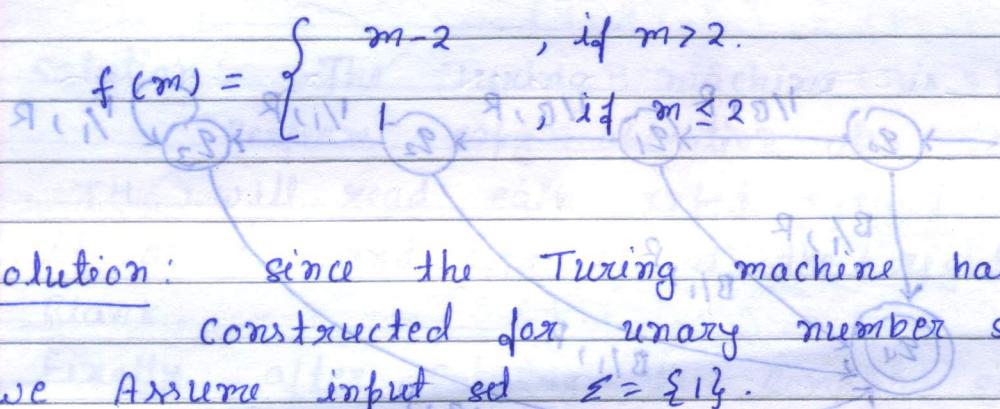
$$\delta(q_2, B) = (q_3, 1, R) = (1, 1, R)$$

$$(R, 1, 1, R) = (0, 0, 0) 2$$

$$(R, 1, 0, R) = (0, 1, 0) 2$$

$$(R, 0, 1, R) = (0, 0, 1) 2$$

(Q6) construct TM for the function:-



Solution: since the Turing machine has to be constructed for unary number system.
we Assume input set $\Sigma = \{1\}$.

The logic is very simple.

(i) - when $m=0$, then input is BBB.

(ii) when $m=1$, then input is B1B.

(iii) when $m=2$, then input is B11B.

(iv) when $m=3$, then input is B111B.

(v) when $m=4$, then input is B1111B.

$$(9, 7, 1) = (1, 1, 1)_2$$

(i) when $m \leq 2$.

$$(9, 1, 1) = (0, 1, 1)_2$$

$$(9, 0, 1) = (1, 1, 0)_2$$

(i) If read Blank at start then replace Blank to '1' & Enter into final state.

(ii) Replace the first '1' to Blank and scan Blank at second position then replace Blank to 1.

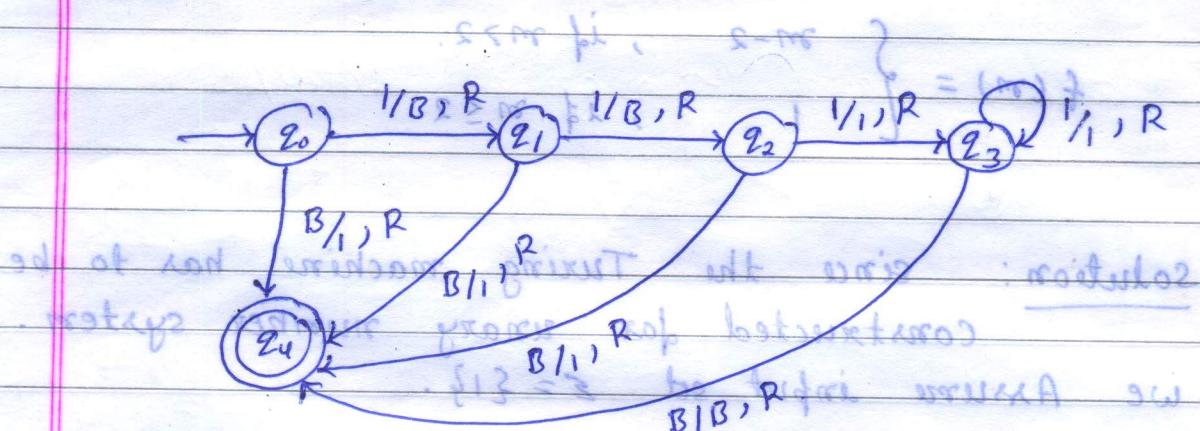
& Enter into final state.

(iii) Replace the first & second '1' to Blank. and scan Blank at Third position then replace Blank to '1' & enter into final state.

(2) when $m > 2$.

Replace first & second '1' to Blank. then scan the '1's & move towards right until the Blank is found. then TM enters into final stat.

SO - waiting int ref MT structures (20)

Define Transition diagram of INT

SO. A Turing machine is defined by :- (i)

. S is initial result. ($S = m$ initially) (ii) $M = \{ (q_0, q_1, q_2, q_3, q_4), \{0, 1\}, \{I, B\}, \delta, q_0, B, q_4 \}$ S is defined by :- ($S = m$ initially) (iii)S is defined by :- ($S = m$ initially) (iv)

$$S(q_0, 1) = (q_1, B, R)$$

$$S(q_0, B) = (q_4, 1, R)$$

$$S(q_1, 1) = (q_2, B, R)$$

So $S(q_1, B) = (q_4, 1, R)$ here I (i)So $S(q_2, 1) = (q_3, 1, R)$ i.e. extra B '1' atSo $S(q_2, B) = (q_4, 1, R)$ with out extra B (ii)So $S(q_3, 1) = (q_3, 1, R)$ i.e. move to same state

$$S(q_3, B) = (q_4, B, R)$$
 with extra B at

here I at '1' because & trip with B (iii)

so move wait waiting point to same more

state having extra waiting & '1' at

S < m initially (2)

so note 2 result. So at '1' because & trip with B
because it break int between tape without move to '1'
So wait having extra waiting MT result

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Q7) Construct TM for copying the input binary string on the tape.

$$(q, x, \{s\}) = (l, \{s\}) 2$$

Solution: The Turing machine is capable to perform copy operation - also. This TM will read each input symbol and mark it as x and copy it at the right end after blank.

$$(l, l, \{s\}) = (q, \{s\}) 3$$

Finally after copying the complete string we will move left and reconvert ' x ' to again.

$$(q, l, \{s\}) = (l, \{s\}) 2$$

The TM will be as follows. ($x, \{s\}$) 3

$$(l, l, \{s\}) = (x, \{s\}) 3$$

$$B \ 1 \ 1 \ 1 \ 1 \ B \quad (l \Rightarrow l \ B) \ x \ x (x \ B) \ 1 \ 1 \ 1 \ B$$

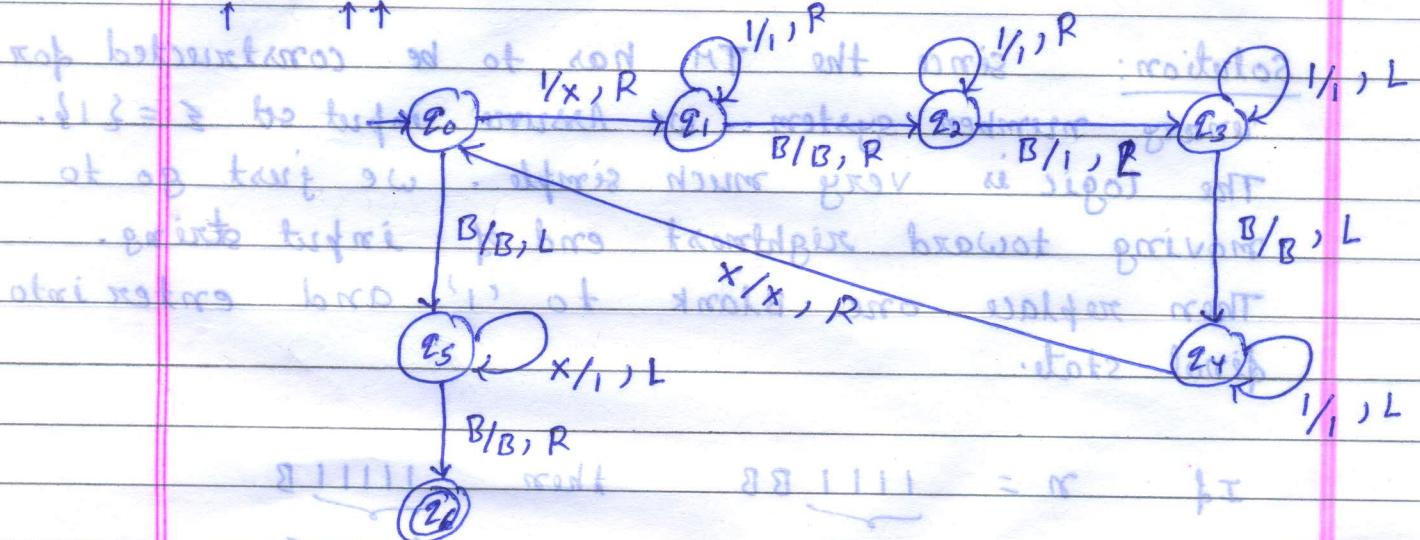
after copying:-

$$B \ 1 \ 1 \ 1 \ 1 \ B \ 1 \ 1 \ 1 \ 1 \ B.$$

↑ original copy. (20)

$$B \ X \ X \ X \ B \ # \ # \ # \ B$$

↑ ↑



- Transition diagram:-

So, the Turing Machine M is defined by:-

$$M = (\{20, 21, 22, 23, 24, 25, S\}, \{1, x, B\}, S, 20, B, 25).$$

$$(q, x, \{s\}) = (l, \{s\}) 2$$

figures are defined as right not MT structures
- don't have no groups

$$S(Q_0, 1) = (Q_1, X, R)$$

$S(2_0, B) = \pi((2_5, B, \rho))_{\text{NT}}$: resultados

$$\text{right } \delta((z_1, 1)) = ((z_1, 1), R) \text{ of } \alpha$$

~~order~~ $S_0(Q_1, B) \cong (Q_2, B, R)$ base line MT

~~so that~~ $b \circ S(Q_2, R) = t(Q_2, R)$ is bireciprocal to the

$$\delta(q_2, B) = (q_3, 1, L)$$

$$\text{proj}_{\ell}(93, 1) = (93, 1, L)$$

riops $(123)B = (24)B, L$ biras tpej asom uiw

$$S(Q_4, 1) = (Q_4, 1, L)$$

$S(2_4, x) = (2_{01}, x, R)$ ad liw MT ENT

$$S(95, x) = (95, 1, L)$$

$$S((\varphi_1, B)) = (\varphi_1, B, L)$$

- : Briggs 2930

Q8) Construct a TM for a successor function for a given unary number i.e. $f(n) = n+1$, $n > 0$.

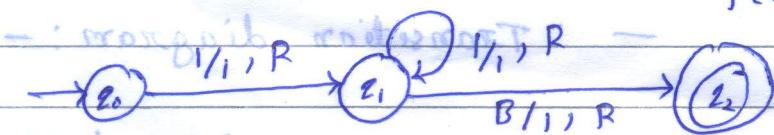
Solution: since the TM has to be constructed for unary number system. We Assume input set $\Sigma = \{1\}$.

The logic is very much simple. we first go to

moving toward rightmost end of input string.

Then replace one blank to '1' and enter into final state.

$$\text{If } n = \underbrace{1111}_{n=4} BB \text{ then } \underbrace{11111}_f(n) = B$$



Turing Machine $M = (\{q_0, q_1, q_2\}, \Sigma^*, \delta, q_0, q_1)$

S is defined $S(2_0, 1) = (2_1, 1, B)$, $S(2_1, 1) = (2_2, 1, B)$

$$\delta(q_1, B) = (q_3, 1, B).$$

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(g) construct a TM for obtaining one's complement of (for a given binary) numbers using D P

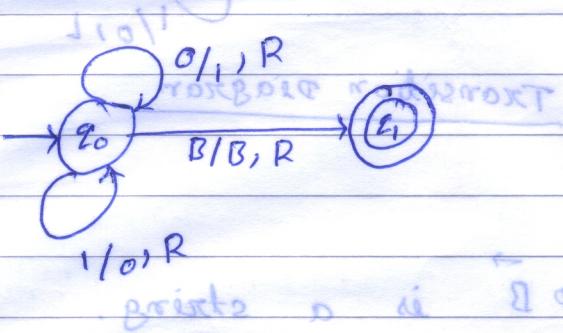
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82M of Prover that g is function iff $f(\omega) = \bar{\omega}$ where ω is computable where $\omega \in \{0, 1\}^*$ and $\bar{\omega}$ is one's complement of ω .

Solution 2w 82) $\text{mole} \cdot \text{L}^{-1} \cdot \text{min}^{-1}$ graphene effA

To make λ the I^* complement while the head is reading the input symbol from left to right, the $0's$ are replaced by I^* 's and I^* 's are replaced by 0 's.

If the string is 10110_B then
its complement is 01001_B .



The Turing Machine is :-

$$M = (\{z_0, z_1\}, \{0, 1\}, \{0, 1, B\}, \{s_2, z_0, B, z_1\}).$$

where δ is defined by :-

$$(28, 8, 0.8, 3.48 \times 10^3, 81.0^3, \{28, 48, 100, 98\}) = M$$

$$S(2_0, 0) = (2_0, 1, R) \quad \text{--: yel berisih ke 2}$$

$$(1, 1, \sqrt{3}) \delta (-2a, 0) \in \mathcal{C}(-2a, 0, R)(0, 0) = (0, 0, 0) \delta$$

$$(1, 0, \infty) \otimes (20, B) = (21, B, R) = (1, 0, 8) \otimes$$

$$(x_1, x_2, x_3) = (y_1, y_2) \cdot z \quad | \quad (z, y_1, y_2) = (y_1, y_2) \cdot z$$

$$(1, 0, 1, 8) = (0, 1, 8) \beta$$

$$(1, 1, \dots, 1) = (1, 1, \dots, 1) \cdot 2$$



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classmate
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Example of Two-way Infinite Tape:-

- (a) construct TM for obtaining two's complement of a given binary number (using Two way infinite tape)

Solution: The logic for computing two's complement

is, we read the binary string from LSB to MSB. From LSB, we keep all the zero's as it is.

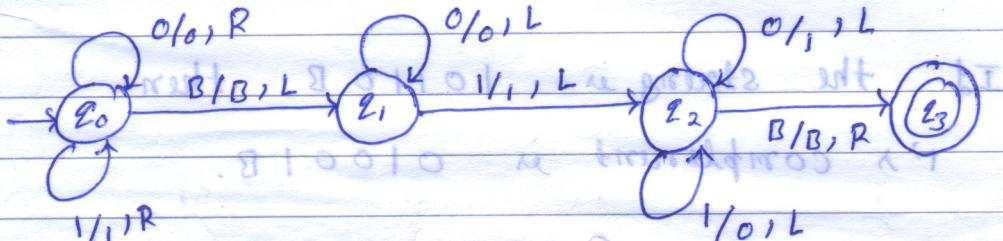
and move left till we do not get 1.

After reading first 1 from LSB we move left and thereafter we convert 0 to 1 and 1 to 0.

and go on moving left. In brief we

The process continues upto left most Blank tape

before



Transition diagram

Example:-

$B\ 100111000\ B$ is a string.

After two's complement $B\ 0110001000\ B$

Turing Machine M is defined as (Two-way infinite tape)

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

S is defined by :-

$$S(q_0, 0) = (q_0, 0, R) \quad S(q_2, 0) = (q_2, 1, L)$$

$$S(q_0, 1) = (q_0, 1, R) \quad S(q_2, 1) = (q_2, 0, L)$$

$$S(q_0, B) = (q_1, B, L)$$

$$S(q_2, B) = (q_3, B, R)$$

$$S(q_1, 0) = (q_1, 0, L)$$

$$S(q_1, 1) = (q_2, 1, L)$$

(ii) construct a Turing Machine for the subroutine $f(a,b) = a * b$, where a and b are unary numbers.

02

construct a Turing machine for multiplication of two numbers.

Let's consider a solution. Here we represent binary number by 1's and 0's. Suppose $x \in \{1, 0\}^n$. Then we have two

Let two numbers i and j be stored into Tape separated by 0. (Two-way \uparrow infinite Tape).

(a) Before the upper stage lifts off, the fuel tank is empty.

I₂ $a = 4$ and $b = 3$. so $a \star b = 12$.

$$B \underbrace{11111}_a \underbrace{0111}_b \text{ then } \times B \underbrace{11111111111111}_c B$$

$a = 4$ $b = 3$ $a * b = 12$

$$a=4 \qquad b=3$$

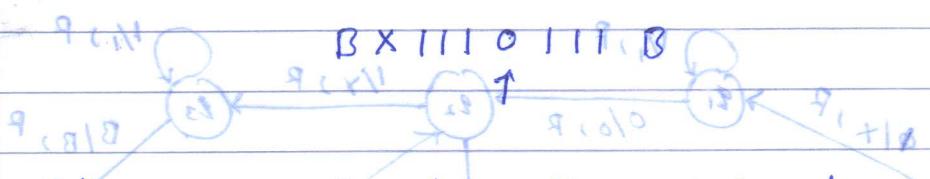
$$a * b = 12$$

4' of 8' x 110 square ft per hour will give you (iv) static head over entire system. Head is static head plus head loss.

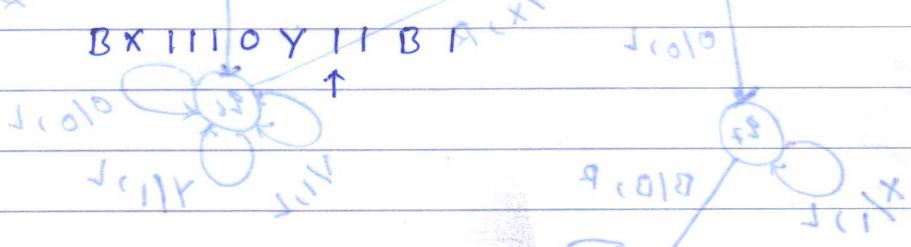
B I I I I O I I I B

↑ B IIII o IIII B IIII B IIII B IIII

ci) Make first one to x and moving to right upto separator o.



iii) Move Right after separator o and Replace I to Y and copy this I after Blank.



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(iii) so mark all i's together after separator, and copy these i's before Blank. $d \neq 0 = (d, 0)$

KO

B X III I O Y Y Y B I I I B

þróunarhlíðum nefnir verðinum ^þ gríðarT o tveiturof
sæðmusei svkt

civ) when copy of all 1's after separator 0 is done
then move left and reconverted already to 1's.
and move left until x is found. then move right.

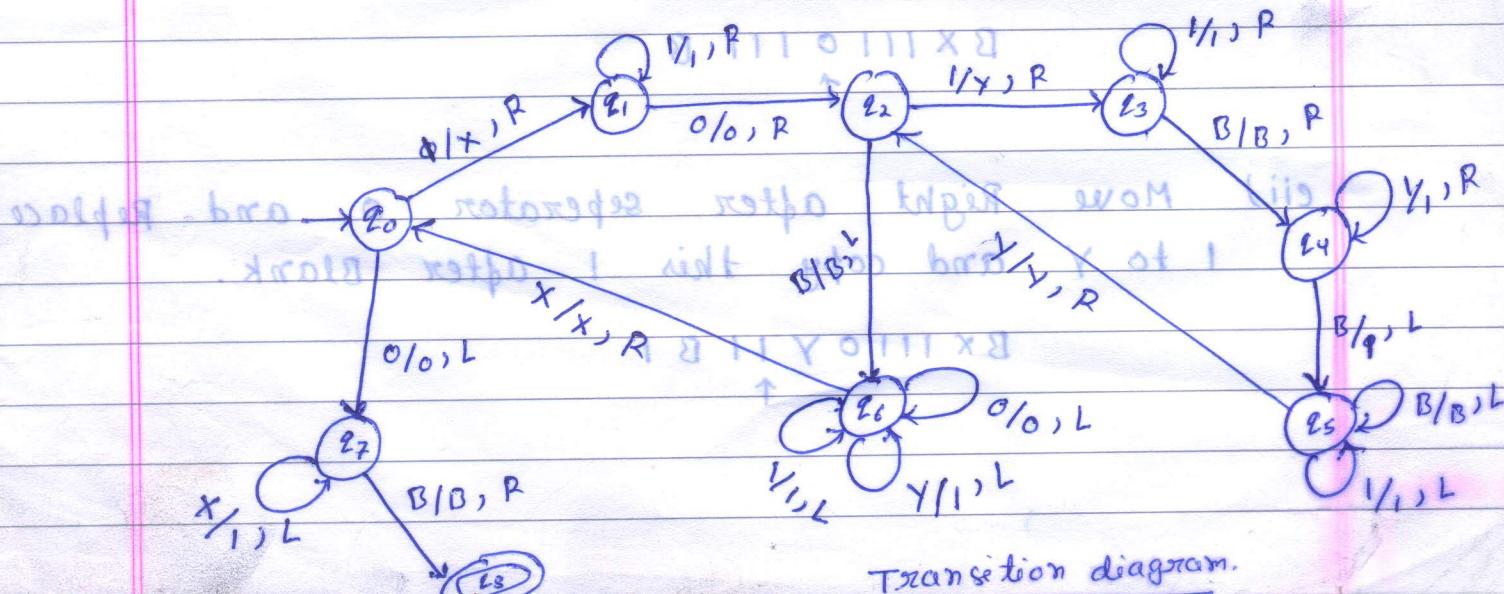
(v) Repeat the above steps until all 1's replaced by X
before separator 0. $\Sigma = \{d, b, 0\}$ $V = \emptyset$ I

(vi) Now we will move left changes all x's to 1's.
and when blank is found. Enter into final state.

8 111 0 1111 8

$$B \text{ } ||| \text{ } | \text{ } o \text{ } ||| \text{ } B \text{ } \overbrace{||||| \text{ } ||| \text{ } ||| \text{ } |||}^{\text{at } 210 \text{ min}} \text{ } B \uparrow$$

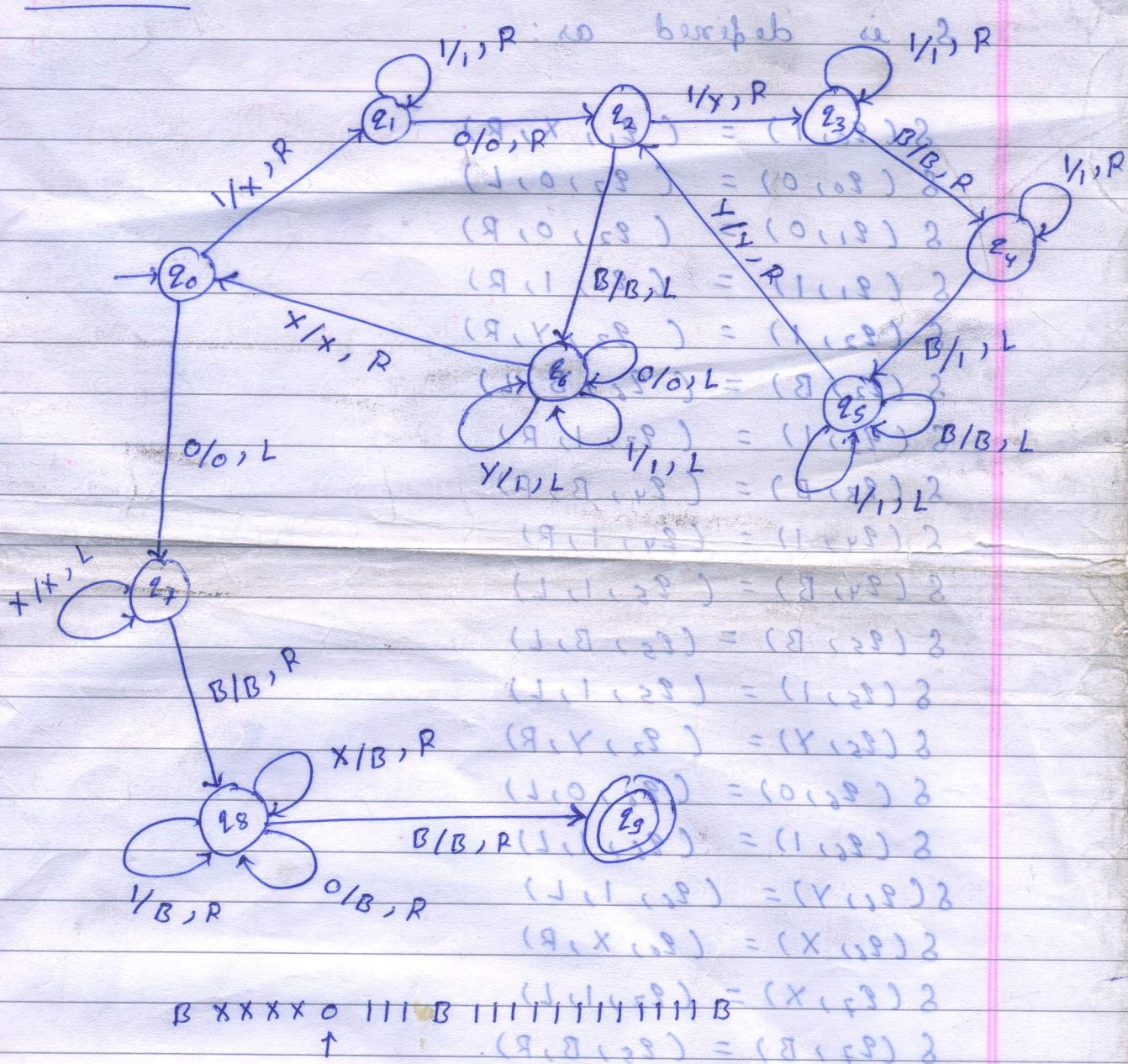
~~at 10 min born~~ $a = 4$ $b = 3$ $a * b = 12$. \therefore xotorgqes otqur $B \text{ } \overbrace{XXXXX \text{ } o \text{ } XXXX}^{\text{at } 210 \text{ min}} \text{ } B \uparrow$



(Q12) construct a briefling machine which performs multiplication.

~~for all $\{x_i\}$, $\{f(x_i)\}$, $\{\|f(x_i)\|\}$, $\Rightarrow \underline{\lim} f(x_i) = L$ in this form)~~

Solution :-



Now we will move left until blank is found.

0^m is ~~BXXXXX0111B1111D11111B before~~

Move right & Replace all x , o & ! to blank until next blank is found.

when next blank is found. enter into final state

B I I I I I I I I I I I B

(50)

Turing Machine is defined by transitions

$$M = (\{ \# 2_0, 2_1, 2_2, 2_3, 2_4, 2_5, 2_6, 2_7, 2_8 \}, \{ 0, 1, B \},$$

$$\{ S, 2_0, B, 2_8 \}).$$

- : module.

 $\delta_{T,N}$ is defined as:

$$\delta(S(2_0), 1) = (2_1, X, R)$$

$$\delta(S(2_0), 0) = (2_7, 0, L)$$

$$\delta(S(2_1), 0) = (2_2, 0, R)$$

$$\delta(S(2_1), 1) = (2_3, 1, R)$$

$$\delta(S(2_2), 1) = (2_3, Y, R)$$

$$\delta(S(2_2), B) = (2_6, B, L)$$

$$\delta(S(2_3), 1) = (2_3, 1, R)$$

$$\delta(S(2_3), B) = (2_4, B, R)$$

$$\delta(S(2_4), 1) = (2_4, 1, R)$$

$$\delta(S(2_4), B) = (2_5, 1, L)$$

$$\delta(S(2_5), B) = (2_5, B, L)$$

$$\delta(S(2_5), 1) = (2_5, 1, L)$$

$$\delta(S(2_5), Y) = (2_2, Y, R)$$

$$\delta(S(2_6), 0) = (2_6, 0, L)$$

$$\delta(S(2_6), 1) = (2_6, 1, L)$$

$$\delta(S(2_6), Y) = (2_6, 1, L)$$

$$\delta(S(2_6), X) = (2_6, X, R)$$

$$\delta(S(2_7), X) = (2_7, 1, L)$$

$$\delta(S(2_7), B) = (2_8, B, R).$$

Input is $1^m 0^n 1^m$ then output is $1^m 0^n B 1^m$ Input is $1^m 0^n 1^m$ then output is $1^m 0^n B 1^m$

Input of 1 & 0, X No writer & Engine move

Input is $1^m 0^n 1^m$ then output is $1^m 0^n B 1^m$

Input of 1 & 0, X No writer & Engine move