Reg. No.														

B.Tech. DEGREE EXAMINATION, DECEMBER 2022
OPEN BOOK EXAMINATION
Fourth/ Fifth Semester

18CSC301T – FORMAL LANGUAGE AND AUTOMATA
(For the candidates admitted from the academic year 2018-2019 to 2021-2022)

- Specific approved THREE text books (Printed or photocopy) recommended for the course
- Handwritten class notes (certified by the faculty handling the course / head of the department)

Time: 3 Hours | Max. Marks: 100

Answer **FIVE** questions
(Question: No 3 is compulsory)

		Marks	BL	CO	PO
1.	Abi has red and blue color balls and wanted to play a game. She puts all the balls in a bag and she wanted to pick the balls in the specified order. If she picks the red ball, blue ball, and red ball in a sequence at least once, it is a success.				
i.	Write a regular expression (RE) for the above scenario.	2	3	1	4
ii.	Construct ϵ-NFA for the RE using Thompson's construction method.	4	3	1	4
iii.	Convert this ϵ-NFA into deterministic finite automata (DFA) using subset construction method.	8	5	1	6
iv.	Minimize the DFA.	4	5	1	6
v.	Which of the following are true (A) A language accepted by a DFA is also accepted by some NFA but not vice versa (B) A language accepted by a DFA is also accepted by some NFA and vice versa (C) NFA is a 6 tuple (D) DFA is 5 tuple but not NFA	1	4	1	2
vi.	A transition from a state to another state without reading any input is allowed in _____. (A) DFA (B) NFA (C) ϵ-NFA (D) RE	1	4	1	2
2.	Babu has to travel from his office to his home every day. He can use four routes, A, B, C and D. Each month he has to take route A and route D equally, and route B and route C equally. He has to travel in all the routes at least once. In each given duration be needs to take route A first for n number of days followed by taking up route B for m number of days, followed by route C and route D as per the given condition.				

i.	Construct a turing machine for case (i).	8	3	4	4
ii.	Construct a turing machine without using subroutine for the case (ii).	10	3	4	4
iii.	Turing machine is more powerful than: (A) Finite automata (B) Push down automata (C) Both (A) and (B) (D) None of these	1	4	4	2
iv.	Initially the tape head is pointing the (A) Rightmost cell that holds the input (B) Leftmost cell that holds the input (C) Middle cell that holds the input (D) None of the above	1	4	4	2
7.	Adhitya and Arulmozhi wanted to play a game. One has to tell a binary number, and the other one has to check whether that number is divisible by 2. If it is divisible by 2, it is assumed as success.				
i.	Construct a turing machine for the above scenario.	4	3	5	4
ii.	Convert the above turing machine into modified post correspondence problem (MPCP). Show the ID and MPCP solution for the input string "100".	8	3	5	4
iii.	Write the code for the above turing machine.	6	3	5	4
iv.	Which of the following statements are false? (A) Every recursive language is recursively enumerable (B) Recursively enumerable language may not be recursive (C) Recursive languages may not be recursively enumerable (D) None of the mentioned	1	4	5	2
v.	If a problem has no algorithm to answer it, we call it _____. (A) Decidable (B) Solved (C) Recognizable (D) None of the mentioned	1	4	5	2

* * * * *

i. Construct CFG for the above scenario. 3 3 2 4

ii. Construct language for the CFG. 3 3 2 4

iii. Derive the suitable string from the CFG using left most derivation, right most derivation and parse tree. 6 5 2 6

iv. Check whether the grammar is ambiguous or not by taking any string of length at least six. 6 3 2 6

v. Which among the following is not a part of the context free grammar tuple? 1 4 2 2
(A) Variable (B) Start symbol
(C) End symbol (D) Production

vi. I: context free grammar is a subset of context sensitive grammar. 1 4 2 2
II: Regular grammars are the most restricted type of grammars.
(A) Both are false (B) Both are true
(C) I is false and II is true (D) II is false and I is true

3. Consider the following grammar

S → NP VP | Aux NP VP | VP
NP → Det Nom
Nom → Noun | Noun Nom
VP → Verb
VP → Verb NP
Det → that | this | a | the
Noun → ball | flight | meal | man
Verb → book | include | hit
Aux → does

i. List the terminal and non-terminal symbols. 3 4 2 2

ii. Check if the above grammar could generate the string "the man hit the ball". 4 3 2 4

iii. Simplify the grammar. 7 3 2 4

iv. Convert the above CFG to Chomsky normal form (CNF). 4 3 2 4

v. How many productions in the CFG are already in CNF? 1 4 2 2
(A) 16 (B) 12
(C) 4 (D) 13

vi. The given productions are type _____ grammar. 1 4 2 2
(A) 0 (B) 1
(C) 2 (D) 3

4. The school organized a children's day celebration event for all its students. The students participated in various games of the events. One such game is picking the color flowers from the pool. The student has to pick the flowers in the order specified. The one who is picking all the flowers in the specified order at the earliest is the winner. The colored flowers are red, green, violet and yellow.

Case (i) : First they should pick 'n' number of red flowers then 'm' number of green flowers then '2 m' number of violet flowers and at least '3 n' number of yellow flowers.
Case (ii) : First they should pick 'n' number of red flowers then '4 n' number of green flowers.

i. Write the language for both the cases using set former. 5 4 3 2

ii. Construction of PDA for both the cases. 8 3 3 4

iii. Check whether one red flower followed by 4 green flowers can be picked using instantaneous description in case (ii)'s PDA? 5 3 3 4

iv. What can be inferred from the PDAs constructed for the given scenario? 1 4 3 2
(A) The PDA constructed for case (i) is non deterministic
(B) The PDAs constructed for case (i) and case (ii) are deterministic
(C) The PDA constructed for case (ii) is non deterministic
(D) The PDAS constructed for case (i) and (ii) are non-deterministic

v. What can be said about the language accepted by a PDA with 121 stack elements? 1 4 3 2
(A) Regular (B) Context free
(C) Recursive (D) Nothing can be inferred

5. Goutham wants to reduce his weight he decides to join in gym and tries to use tread mill and cycle. If he used thread mill for the first 'n' number of days he has to use cycle for the next '2n' number of days.

i. Construct context free grammar for the above scenario. 2 3 3 4

ii. Convert the CFG into PDA. 6 3 3 4

iii. Show the instantaneous description for using tread mill 2 times and using cycle 4 times. 4 3 34

iv. Check whether the language $L=\{a^n b^m c^n d^m \mid n,m \geq 1\}$ is not a CLF using pumping Lemma. 6 3 3 4

v. A push down automaton employs _____ data structure. . 1 4 3 2
(A) Queue (B) Linked list
(C) Hash table (D) Stack

vi. The language generated for the given scenario is _____. 1 4 3 2
(A) Regular (B) Context free language
(C) Context sensitive language (D) Recursively enumerable language

6. Case (i): Nandhini and Vanathi wanted to play a word (string) game, and the string can be made up of 2 symbols. One has to tell a string, and the other one has to check whether that string and its reverse are same.
Case (ii): There are totally P number of students. Each student has to sell q tickets for an event. How many tickets are sold altogether?

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B.Tech Degree Examination – DECEMBER 2022

Open Book Examination

18 CSC301T – Formal Language and Automata

Answer key.

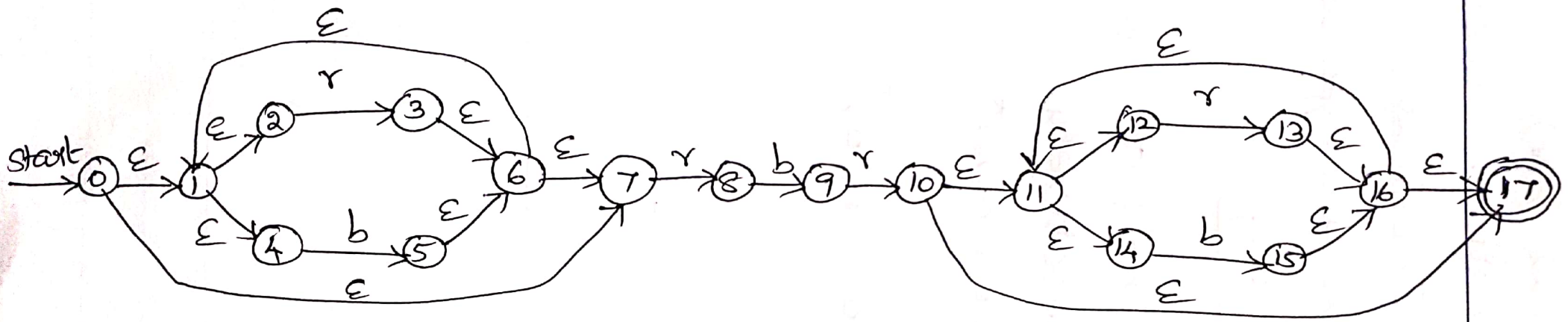
1. red ball and blue ball can be represented as 'r' and 'b' respectively.

(i) $RE = (r+b)^* rbr (r+b)^*$ (2 Marks)

(or)

$RE = (r|b)^* rbr (r|b)^*$

(ii) ε-NFA (4 Marks)



ECLOSURE (3 Marks)

(iii)

ECLOSE(0) = {0, 1, 2, 4, 7}

ECLOSE(1) = {1, 2, 4}

ECLOSE(2) = {2}

ECLOSE(3) = {3, 6, 1, 7, 2, 4}

ECLOSE(4) = {4}

ECLOSE(5) = {5, 6, 1, 7, 2, 4}

ECLOSE(6) = {6, 1, 7, 2, 4}

" (7) = {7}

" (8) = {8}

" (9) = {9}

" (10) = {10, 11, 12, 14, 17}

" (11) = {11, 12, 14}

" (12) = {12}

" (13) = {13, 16, 11, 17, 12, 14}

" (14) = {14}

" (15) = {15, 16, 11, 17, 12, 14}

" (16) = {16, 11, 17, 12, 14}

" (17) = {17}

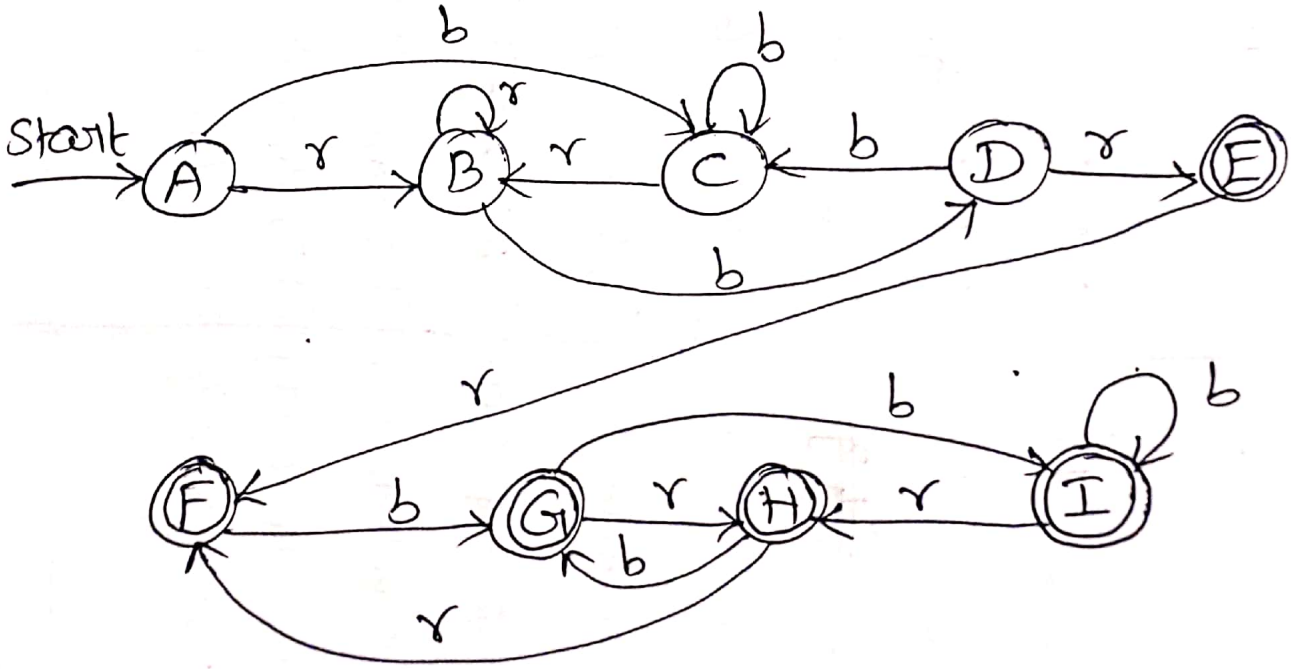
DFA (5 Marks)

States	a	b
→ {0, 1, 2, 4, 7}	{1, 2, 3, 4, 6, 7, 8}	{1, 2, 4, 5, 6, 7}
{1, 2, 3, 4, 6, 7, 8}	{1, 2, 3, 4, 6, 7, 8}	{1, 2, 4, 5, 6, 7, 9}
{1, 2, 4, 5, 6, 7}	{1, 2, 3, 4, 6, 7, 8}	{1, 2, 4, 5, 6, 7}
{1, 2, 4, 5, 6, 7, 9}	{1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 14, 17}	{1, 2, 4, 5, 6, 7}
*{1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 14, 17}	{1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, 16, 17}	{1, 2, 4, 5, 6, 7, 9, 11, 12, 14, 15, 16, 17}
*{1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, 16, 17}	{1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, 16, 17}	{1, 2, 4, 5, 6, 7, 9, 11, 12, 14, 15, 16, 17}
*{1, 2, 4, 5, 6, 7, 9, 11, 12, 14, 15, 16, 17}	{1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 14, 17, 13, 16}	{1, 2, 4, 5, 6, 7, 11, 12, 14, 15, 16, 17}
*{1, 2, 3, 4, 6, 7, 8, 10, 11, 12, 13, 14, 16, 17}	{1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, 16, 17}	{1, 2, 4, 5, 6, 7, 9, 11, 12, 14, 15, 16, 17}
*{1, 2, 4, 5, 6, 7, 11, 12, 14, 15, 16, 17}	{1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, 16, 17}	{1, 2, 4, 5, 6, 7, 11, 12, 14, 15, 16, 17}

iv) Minimize the DFA.

DFA

		a	b
→	A	B	C
	B	B	D
	C	B	C
	D	E	C
*	E	F	G
*	F	F	G
*	G	H	I
*	H	F	G
*	I	H	I



$\pi_0 = \{\{A, B, C, D\}, \{E, F, G, H, I\}\}$
$\qquad\qquad\quad 1 \qquad\qquad\quad 2$

	A	B	C	D	E	F	G	H	I
r	1	1	1	2	2	2	2	2	2
b	1	1	1	1	2	2	2	2	2

$\pi_1 = \{\{A, B, C\}, \{D\}, \{E, F, G, H, I\}\}$
$\qquad\quad 3 \qquad\quad 4 \qquad\qquad\quad 2$

	A	B	C	D	E	F	G	H	I
r	3	3	3	2	2	2	2	2	2
b	3	4	3	3	2	2	2	2	2

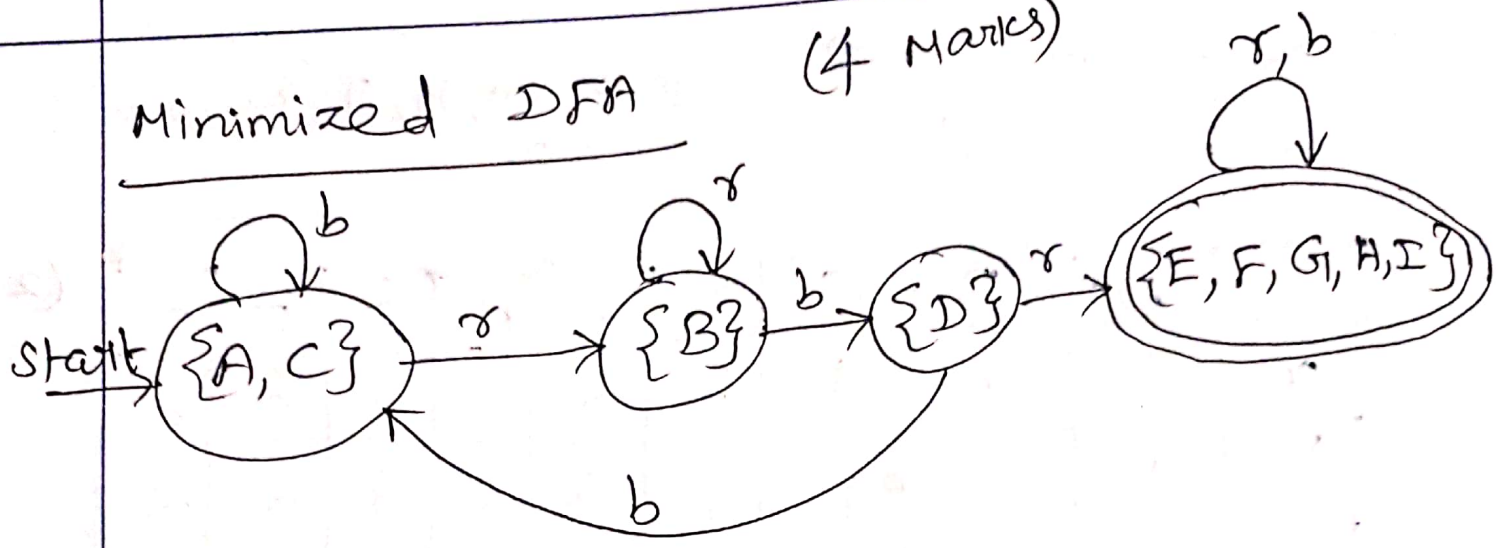
$\pi_2 = \{\{A, C\}, \{B\}, \{D\}, \{E, F, G, H, I\}\}$
$\qquad\quad 5 \qquad\quad 6 \qquad\quad 4 \qquad\qquad\quad 2$

	A	B	C	D	E	F	G	H	I
r	6	6	6	2	2	2	2	2	2
b	5	4	5	5	2	2	2	2	2

$\pi_3 = \{\{A, C\}, \{B\}, \{D\}, \{E, F, G, H, I\}\}$

π_3 is Same as π_2

Minimized DFA (4 Marks)



v) (B)

vi) (C)

2. Routes A, B, C and D are considered as a, b, c and d respectively.

(i) CFG

CFG, $G = (\{S, A\}, \{a, b, c, d\}, P, S)$ (1 M)

$P = \{ \; S \to aSd \mid aAd$

$A \to bAc \mid bc \; \}$ (2 M)

(ii). Language for the CFG. (3 Marks)

$L(G) = \{a^n b^m c^m d^n \mid n \geq 1, m \geq 1\}$

(iii) Any string can be chosen. Let us take string = "aabcdd"

Leftmost derivation (2 Marks)

$$S \underset{lm}{\Rightarrow} aSd \underset{lm}{\Rightarrow} aaAddd \underset{lm}{\Rightarrow} aabcdd$$

Rightmost derivation (2 Marks)

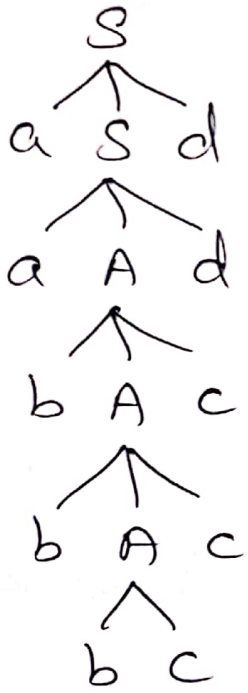
$$S \underset{rm}{\Rightarrow} aSd \underset{rm}{\Rightarrow} aaAddd \underset{rm}{\Rightarrow} aabcdd$$

Parse Tree (2 Marks)

(iv) Ambiguous or Not.

Let string = "aabbbcccdd"

(4 Marks)



(2 Marks)

We can construct only 1 parse tree for this string. Hence the grammar is unambiguous.

v) (C)

vi) (B)

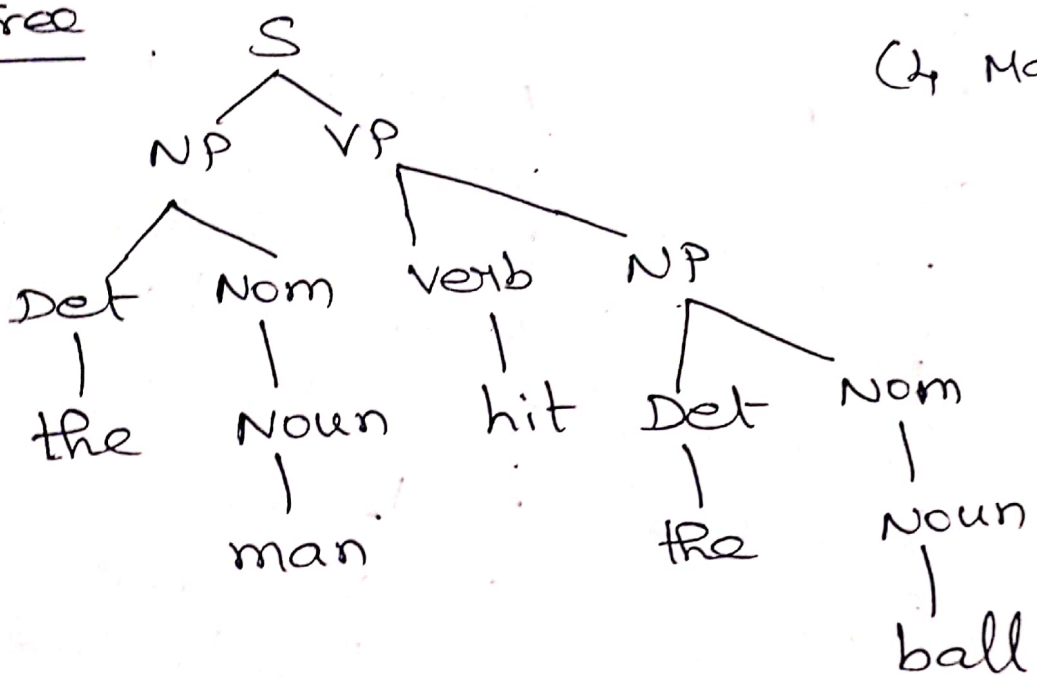
3.

(i) Terminals = { that, this, a, the, ball, flight, meal, man, book, include, hit, does } (1.5 Marks)

Non-terminals = { S, NP, VP, Nom, Det, Noun, Verb, Aux } (1.5 Marks)

(ii) Left-most derivation or rightmost derivation or parse tree can be used for proving. (4 Marks)

Parse Tree



(iii) Simplification of Grammar.

Elimination of ε-productions (1 Mark)

No ε-productions in this grammar.

Elimination of Unit productions (4 Marks)

Unit pairs	Not unit productions
(S, S)	S → NP VP | Aux NP VP
(NP, NP)	NP → Det Nom
(Nom, Nom)	Nom → Noun Nom
(VP, VP)	VP → verb NP
(Det, Det)	Det → that | this | a | the
(Noun, Noun)	Noun → ball | flight | meal | man
(verb, verb)	Verb → book | include | hit
(Aux, Aux)	Aux → does
(S, VP)	S → verb NP
(S, verb)	S → book | include | hit
(Nom, Noun)	Nom → ball | flight | meal | man
(VP, verb)	VP → book | include | hit

S → NP VP | Aux NP VP | Verb NP | book | include | hit

NP → Det Nom

Nom → Noun Nom | ball | flight | meal | man

VP → verb NP | book | include | hit

Det → that | this | a | the

Noun → ball | flight | meal | man

Verb → book | include | hit

Aux → does.

Elimination of useless Symbols. (2 Marks)

Generating symbols = { that, this, a, the, ball, flight, meal, man, book, include, hit, does, VP, Nom, Aux, Verb, Noun, Det, NP, S }

Reachable symbols = { S, NP, VP, Aux, Verb, book, include, hit, Det, Nom, Noun, ball, flight, meal, man, that, this, a, the, does }

There are no ∴ non-generating and non-reachable symbols. So there are no useless symbols.

iv) Chomsky Normal Form (4 Marks)

$C_1 \rightarrow NP\ VP$

$S \rightarrow NP\ VP \mid Aux\ C_1 \mid Verb\ NP \mid book \mid include \mid hit$

$NP \rightarrow Det\ Nom$

$Nom \rightarrow Noun\ Nom \mid ball \mid flight \mid meal \mid man$

$VP \rightarrow verb\ NP \mid book\ include \mid hit$

$Det \rightarrow that \mid this \mid a \mid the$

$Noun \rightarrow ball \mid flight \mid mean \mid man$

$Verb \rightarrow book \mid include \mid hit$

$Aux \rightarrow does$

v) (A)

vi) (C)

4. (i) case (i) Red, green, violet, yellow $\Rightarrow r, g, V, y$

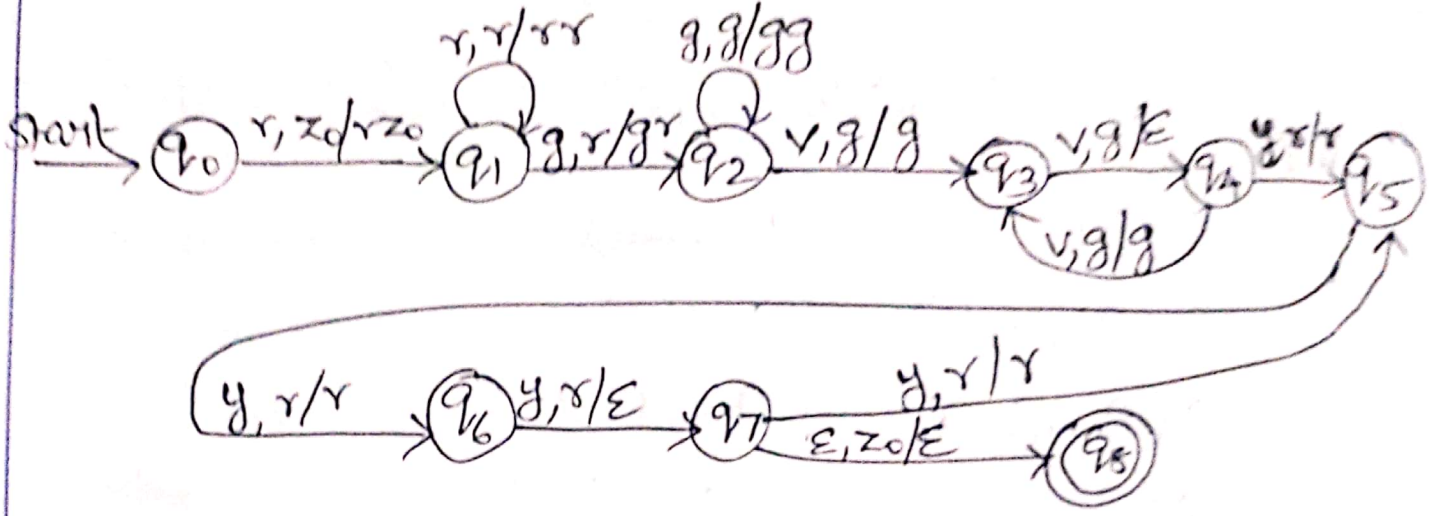
$L_1 = \{ r^n g^m V^{2m} y^{3n} \mid n \geq 1, m \geq 1 \}$ (3 Marks)

case (ii)

$L_2 = \{ r^n g^{4n} \mid n \geq 1 \}$ (2 Marks)

(ii) PDA, $P = (\{q_0, q_1, \ldots q_8\}, \{r, g, v, y\}, \{r, g, z_0\}, \delta, q_0, z_0, \{q_8\})$

(4 MARKS)



$\delta(q_0, r, z_0) = (q_1, rz_0)$

$\delta(q_1, r, r) = (q_1, rr)$

$\delta(q_1, g, r) = (q_2, gr)$

$\delta(q_2, g, g) = (q_2, gg)$

$\delta(q_2, v, g) = (q_3, g)$

$\delta(q_3, v, g) = (q_4, \varepsilon)$

$\delta(q_4, v, g) = (q_3, g)$

$\delta(q_4, y, r) = (q_5, r)$

$\delta(q_5, y, r) = (q_6, r)$

$\delta(q_6, y, r) = (q_7, \varepsilon)$

$\delta(q_7, y, r) = (q_5, \varepsilon)$

$\delta(q_7, \varepsilon, z_0) = (q_8, \varepsilon)$

b) PDA, $P = (\{q_0, q_1, \cdots q_6\}, \{r, g\}, \{r, z_0\}, \delta, q_0, z_0, \{q_6\})$

(4 Marks)

$\delta(q_0, r, z_0) = (q_1, rz_0)$

$\delta(q_1, r, r) = (q_1, rr)$

$\delta(q_1, g, r) = (q_2, r)$

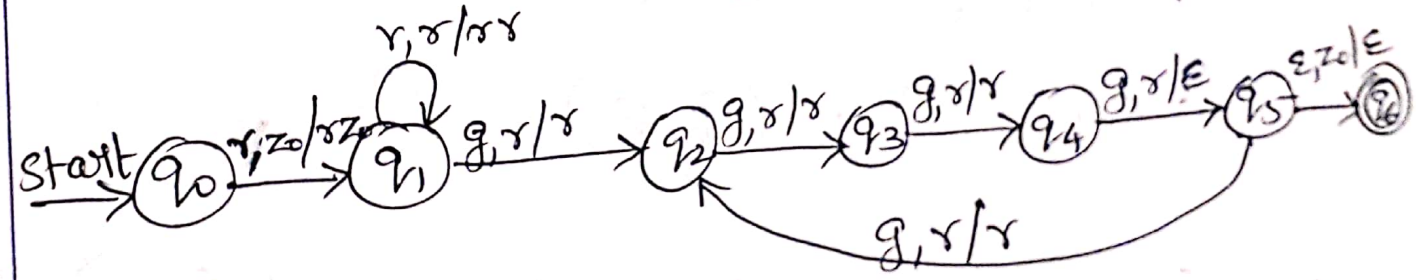
$\delta(q_2, g, r) = (q_3, r)$

$\delta(q_3, g, r) = (q_4, r)$

$\delta(q_4, g, r) = (q_5, \varepsilon)$

$\delta(q_5, g, r) = (q_2, r)$

$\delta(q_5, \varepsilon, z_0) = (q_6, \varepsilon)$



(5 Marks)

(iii) $(q_0, rgggg, z_0) \vdash (q_1, gggg, rz_0)$
$\vdash (q_2, ggg, rz_0)$
$\vdash (q_3, gg, rz_0)$
$\vdash (q_4, g, rz_0)$
$\vdash (q_5, \varepsilon, z_0)$
$\vdash (q_6, \varepsilon, \varepsilon)$

So 1 red flower followed by 4 green flowers are picked.

iv) (B)

v) (D)

5. Thread mill and cycle $\Rightarrow$ t & c

(i) CFG, $G=(\{S\}, \{t, c\}, P, S)$ (2 Marks)

$P=\{ S \rightarrow tScc \mid tcc \}$

(ii) PDA

PDA, $P=(\{q\}, \{t, c\}, \{S, t, c\}, \delta, q, S)$ (2 Marks)

$\delta(q, \varepsilon, S) = \{(q, tScc), (q, tcc)\}$ (4 Marks)

$\delta(q, t, t) = (q, \varepsilon)$

$\delta(q, c, c) = (q, \varepsilon)$

(iii) $(q, ttcccc, S) \vdash (q, ttcccc, tScc)$ (4 Marks)

$\vdash (q, tcccc, Scc)$

$\vdash (q, tcccc, tcccc)$

$\vdash (q, cccc, cccc)$

$\vdash (q, ccc, ccc)$

$\vdash (q, cc, cc)$

$\vdash (q, c, c)$

$\vdash (q, \varepsilon, \varepsilon)$

iv) $L = \{a^n b^m c^n d^m \mid n, m \geq 1\}$ (6 Marks)

Proof:

* Let L be a CFL
* Let n be a constant
* Let $z = a^n b^m c^n d^m$, $|z| \geq n$
* Split $z = uvwxy$, such that
  (i) $|vwx| \leq n$
  (ii) $vx \neq \varepsilon$
  (iii) $\forall\ i \geq 0$, $uv^i wx^i y \in L$

* $u = a^n b^m$

  $vwx = c^n$ where $|vwx| \leq n$

  $vx = c^{n-p}$ where $|vx| \geq 1$

  $y = d^m$

$uv^i wx^i y = uvv^{i-1} wxx^{i-1} y$

$= uvwx\,(vx)^{i-1} y$

$= a^n b^m c^n (c^{n-p})^{i-1} d^m$

$$= a^n b^m c^n c^{ni-n-pi+p} d^m$$

$$= a^n b^m c^{\cancel{n}+ni-\cancel{n}-pi+p} d^m$$

$$= a^n b^m c^{ni-pi+p} d^m$$

Pick $i=0$, $a^n b^m c^p d^m \notin L$

Hence the language $L=\{a^n b^m c^n d^m \mid n, m \geq 1\}$ is not a CFL.

(v) (D)

(vi) (B)

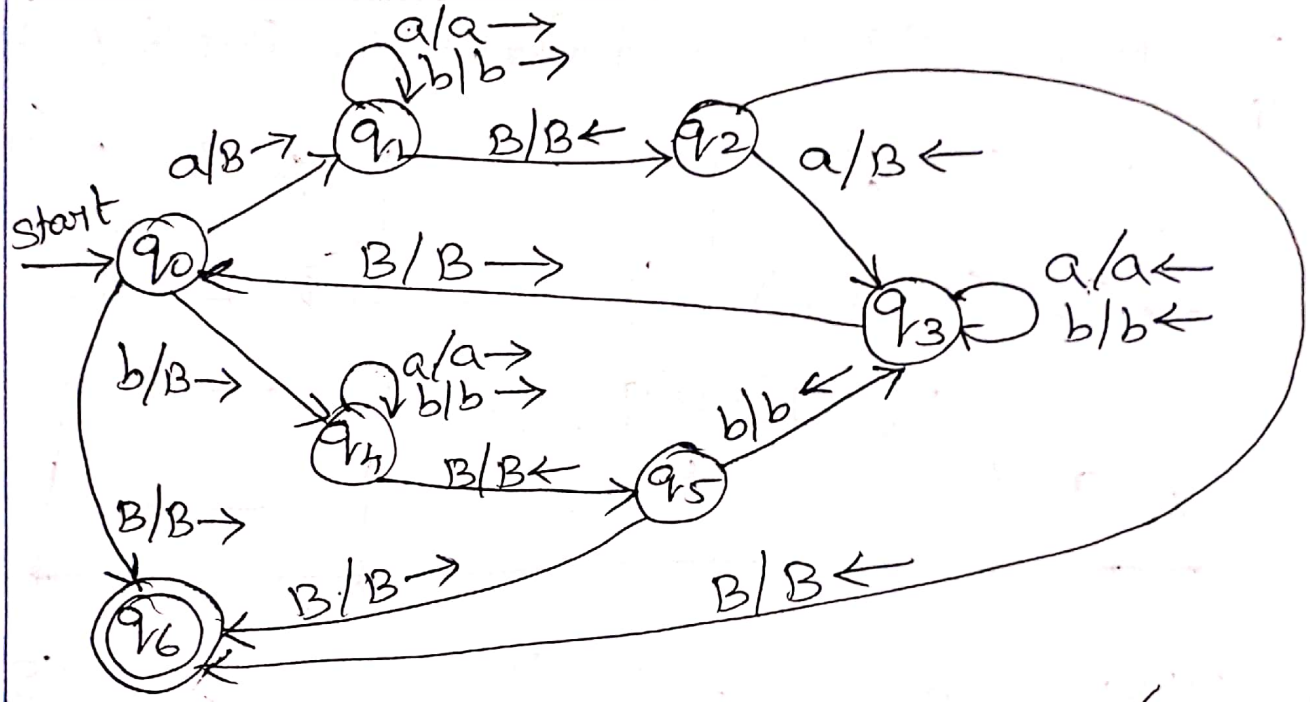
6.(i) Let us assume that the two symbols are a & b. (8 Marks)

δ	a	b	B
$\rightarrow q_0$	(q_1, B, R)	(q_4, B, R)	(q_6, B, R)
q_1	(q_1, a, R)	(q_1, b, R)	(q_2, B, L)
q_2	(q_3, B, L)	—	(q_6, B, R)
q_3	(q_3, a, L)	(q_3, b, L)	(q_0, B, R)
q_4	(q_4, a, R)	(q_4, b, R)	(q_5, B, L)
q_5	—	(q_3, b, L)	(q_6, B, R)
$*\ q_6$	—	—	—

TM, $M = (\{q_0, q_1, \ldots q_6\}, \{a, b\}, \{a, b, B\}, \delta, q_0, B, \{q_6\})$

(or)

Transition Diagram



(10 Marks)

(ii) TM; $M = (\{q_0, q_1, \ldots q_7\}, \{a, b\}, \{a, b, X, B\}, \delta, q_0, B, \{q_7\})$

δ	a	b	X	B
→ q_0	(q_1, B, R)	(q_6, B, R)	—	—
q_1	(q_1, a, R)	(q_2, b, R)	—	—
q_2	(q_3, X, R)	(q_5, b, L)	—	—
q_3	(q_3, a, R)	(q_3, b, R)	—	(q_4, a, L)
q_4	(q_4, a, L)	(q_4, b, L)	(q_2, X, R)	—
q_5	(q_5, a, L)	(q_5, b, L)	(q_5, a, L)	(q_0, B, R)
q_6	(q_6, B, R)	(q_7, b, R)	—	—
* q_7	—	—	—	—

(iii) (C)

(iv) (B)

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

(i) (4 Marks)

δ	0	1	B
$\rightarrow q_0$	$(q_0, 0, R)$	$(q_0, 1, R)$	(q_1, B, L)
q_1	$(q_2, 0, R)$	$(q_1, 1, R)$	—
$* q_2$	—	—	—

(ii) MPCP Instance, $w = 100$ (4 Marks)

Rule	List A	List B	Source
(1)	#	$\#q_0100\#$	
(2)	0	0	
	1	1	
	#	#	
(3)	$q_0 0$	$0 q_0$	$\delta(q_0, 0) = (q_0, 0, R)$
	$q_0 1$	$1 q_0$	$\delta(q_0, 1) = (q_0, 1, R)$
	$0 q_0 \#$	$q_1 0 \#$	$\delta(q_0, B) = (q_1, B, L)$
	$1 q_0 \#$	$q_1 1 \#$	$\delta(q_0, B) = (q_1, B, L)$

(4)	$q_1 0$ $q_1 1$	$0 q_2$ $1 q_1$	$\delta(q_1, 0) = (q_2, 0, R)$ $\delta(q_1, 1) = (q_1, 1, R)$
(5)	$0 q_2 0$ $0 q_2 1$ $1 q_2 0$ $1 q_2 1$ $0 q_2$ $1 q_2$ $q_2 0$ $q_2 1$	q_2 q_2 q_2 q_2 q_2 q_2 q_2 q_2	
(6)	$q_2 \# \#$	$\#$	

ID for 100

$q_0 100 \vdash 1 q_0 00 B$

$\vdash 10 q_0 0 B$

$\vdash 100 q_0 B$

$\vdash 10 q_1 0 B$

$\vdash 100 q_2 B$

(2 Marks)

TM halts. Since q_2 is a final state "100" is accepted.

A: #$q_0$100#1$q_0$00#10$q_0$0#100q_0#10$q_1$0#100q_2#10q_2#1q_2#q_2##

B: #$q_0$100#1$q_0$00#10$q_0$0#100q_0#10$q_1$0#100q_2#10q_2#1q_2#q_3##

∴ MPCP has solution.

(iii) Code for TM

$q_0 \Rightarrow q_1$
$q_1 \Rightarrow q_2$
$q_2 \Rightarrow q_3$

$0 \Rightarrow X_1$
$1 \Rightarrow X_2$
$B \Rightarrow X_3$

$L \Rightarrow D_1$
$R \Rightarrow D_2$

$\delta(q_1, X_1) = (q_1, X_1, D_2)$

$\delta(q_1, X_2) = (q_1, X_2, D_2)$

$\delta(q_1, X_3) = (q_2, X_3, D_1)$

$\delta(q_2, X_1) = (q_3, X_1, D_2)$

$\delta(q_2, X_2) = (q_2, X_2, D_2)$

(4 marks)

$C_1 = 0101010100$

$C_2 = 0100101001 00$

$C_3 = 0100010010 0010$

$C_4 = 0010100010 100$

$C_5 = 0010010010 0100$

Code for TM is

$C_1 \,||\, C_2 \,||\, C_3 \,||\, C_4 \,||\, C_5$ (2 marks)

0101010100 ||0100101001001101000100

0001011001010001001100100100100100

(iv) (c)

(v) (D)