



**COMSATS University
Islamabad**

Compiler Construction

Assignment # 3

Submitted to:

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**Department of Computer Science
2021**

Question #1:

a) $S \rightarrow OS1|01$

Parsing Stack	Input	Action
\$	000111\$	Shift
\$0	00111\$	Shift
\$00	0111\$	Shift
\$000	111\$	Shift
\$0001	11\$	Shift
\$00S	1\$	Reduce $S \rightarrow 01$
\$00S1		Shift
\$0S		Reduce $S \rightarrow OS1$
\$OS1		Shift
\$S		Reduce $\rightarrow S \rightarrow OS1$
\$-		Reduce $S' \rightarrow S$
	\$	Accept

b) $S \rightarrow SS + | SS^* | a$

Parsing Stack	Input	Action
\$	aaa*att\$	Shift
\$a	aa*att\$	reduce $S \rightarrow a$
\$S	aa*att\$	Shift
\$Sa	a*att\$	reduce $S \rightarrow a$
\$SS	a*att\$	Shift
\$SSa	*att\$	reduce $S \rightarrow a$
\$SSS	*att\$	Shift
\$SSS*	a++\$	reduce $S \rightarrow SS^*$
\$SS	a++\$	Shift
\$SSa	++\$	reduce $S \rightarrow a$
\$SSS	++\$	Shift
\$SS+	+\$	reduce $S \rightarrow SS^+$
\$SS	+\$	Shift
\$SS+	\$	reduce $S \rightarrow SS^+$
\$S	\$	reduce $S' \rightarrow S$
\$S'	\$	Accept.

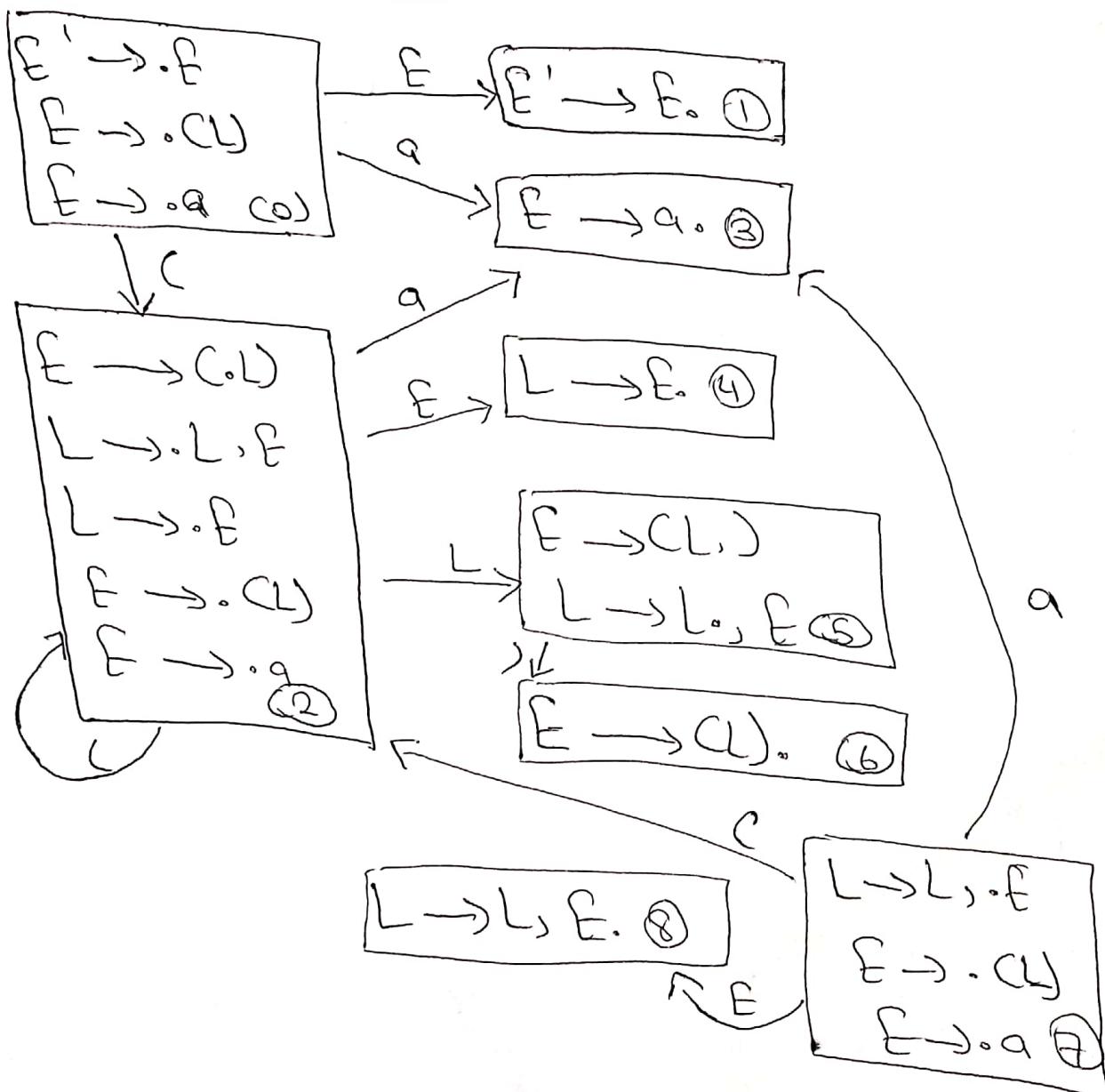
Question # 2:

$$E \rightarrow CL \mid a$$

$$L \rightarrow L, E \mid E$$

Part 1:-

a) DFA for LR(0) items:



SLR(1) Parsing Table

State	Input					Goto	
	()	a	,	\$	E	L
0	S2		S3			1	
1						Accept	
2	S2		S3			4	5
3		γ2		γ2			
4		γ4		γ4			
5		S6		S7			
6		γ1		γ1	γ1		
7	S2		S3			8	
8		γ3		γ3			

The parsing table uses the grammar rules

$$\begin{array}{ll}
 E \rightarrow CL \textcircled{1} & E \rightarrow a \textcircled{2} \\
 L \rightarrow L, E \textcircled{3} & L \rightarrow E \textcircled{4}
 \end{array}$$

also;

$$\text{Follow}(E) = \{ \$,), , , \}$$

$$\text{Follow}(CL) = \{), , \}$$

c)

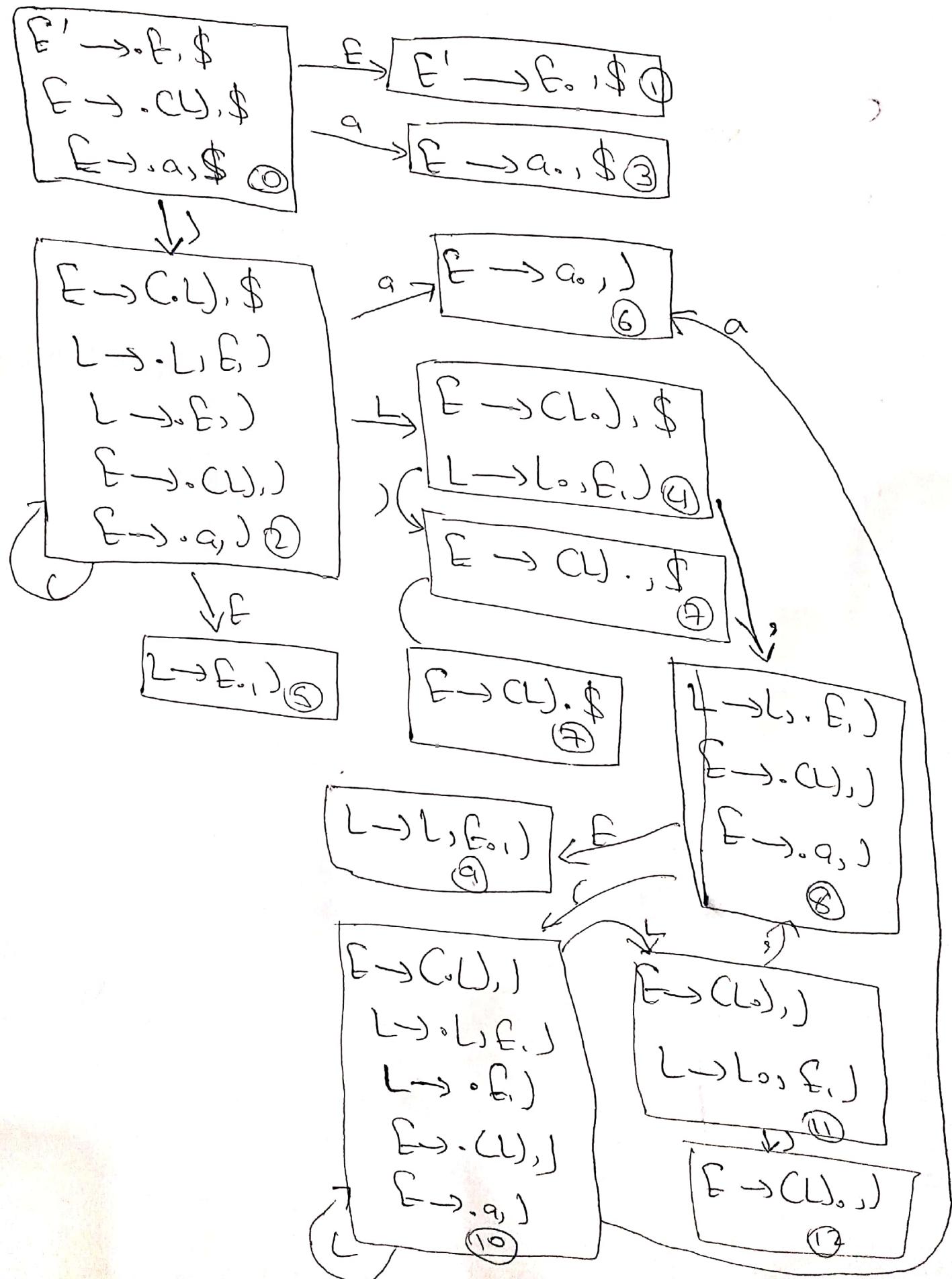
Stack	Input	Action
\$0	((a), a, (a, a))\$	Shift 2
\$0C2	(a), a, (a, a))\$	Shift 2
\$0C2C2	a), a, (a, a))\$	Shift 3
\$0C2C2a3), a, (a, a))\$	Reduce 2
\$0C2C2E4), a, (a, a))\$	reduce 4
\$0C2C2LS), a, (a, a))\$	shift 6
\$0C2C2LS)6	, a, (a, a))\$	reduce 1
\$0C2E4	, a, (a, a))\$	reduce 4
\$0C2LS	, a, (a, a))\$	shift 7
\$0C2LS,7	a, (a, a))\$	shift 3
\$0C2LS,7a3	, (a, a))\$	reduce 2
\$0C2LS,7E8	, (a, a))\$	reduce 3
\$0C2LS	, (a, a))\$	shift 7
\$0C2LS,7	(a, a))\$	Shift 2
\$0C2LS,7C2	a, a))\$	Shift 3
\$0C2LS,7C2a3	, a))\$	reduce 2
\$0C2LS,7C2E4	, a))\$	reduce 4
\$0C2LS,7C2LS	, a))\$	Shift 7

\$ 0C2LSA7C2LS,7	0) \$	Shift 3
\$ 0C2LS,7C2LS,7a3) \$	Reduce 2
\$ 0C2LS,7C2LS,7E8) \$	Reduce 3
\$ 0C2LS,7C2LS) \$	Shift 6
\$ 0 C2L S,7C2LS) 6) \$	Reduce 1
\$ 0C2LS,7E8) \$	Reduce 3
\$ 0C2LS) \$	Shift 6
\$ 0C2LS) 6) \$	Reduce 1
\$ 0E1	\$	Accept.

d) The grammar is LR(0) as each DFA state is a shift state eg state 0, 2, 5 and 7 or a reduce state eg state 1, 3, 4, 6 and 8 all containing a single complete item.

Part 2 :-

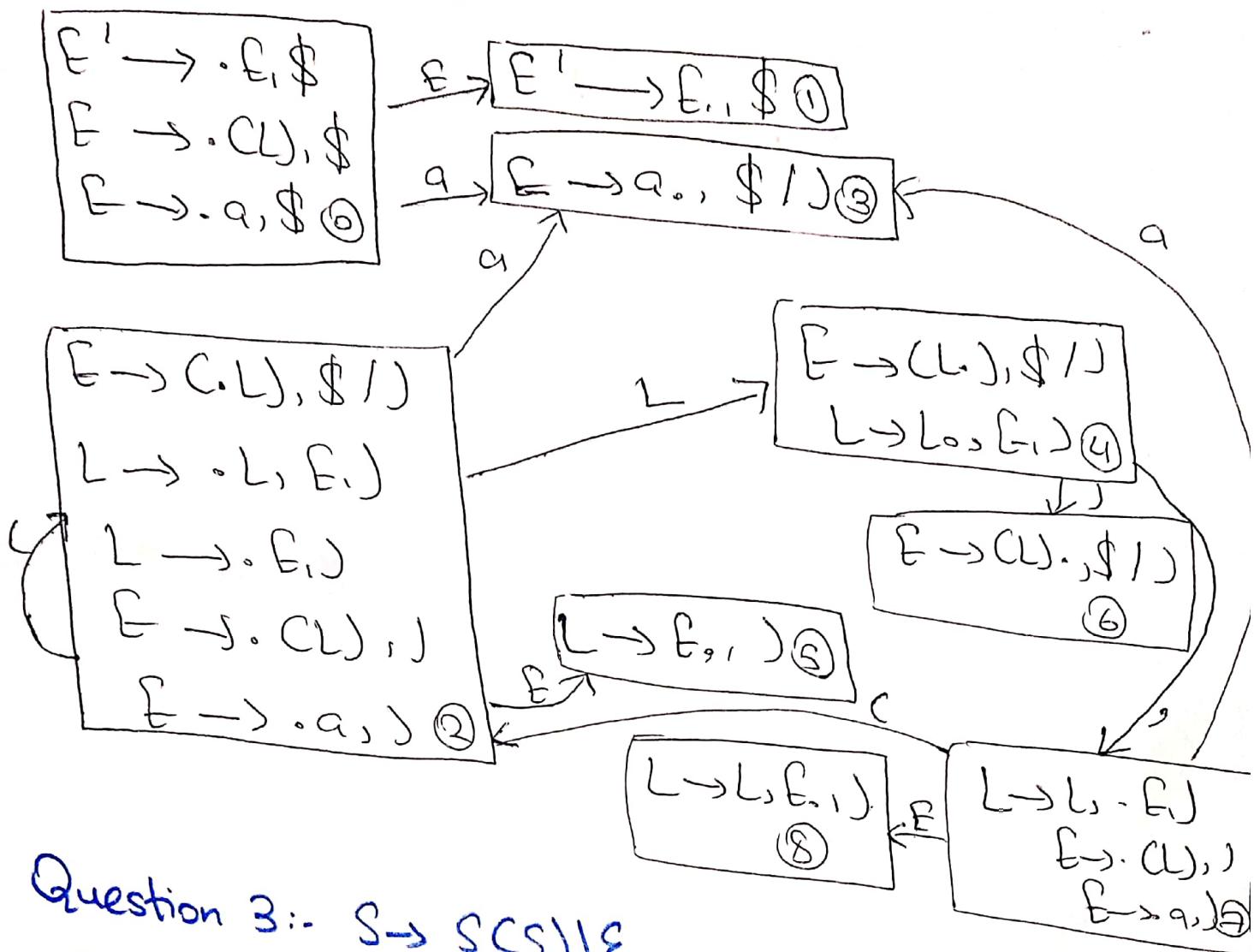
a) DFA for LR(0) items:-



b) LR(1) Parsing Table

State	Input					Goto	
	C)	,	a	\$	E	L
0	S2			S1		1	
1						Accept	
2	S2			S6		5	4
3						x2	
4		S7	S8				
5			x4				
6			x2				
7						x1	
8	S10					9	
9		x3					
10	S10			S6		S	11
11		S12		S8			
12		x1					

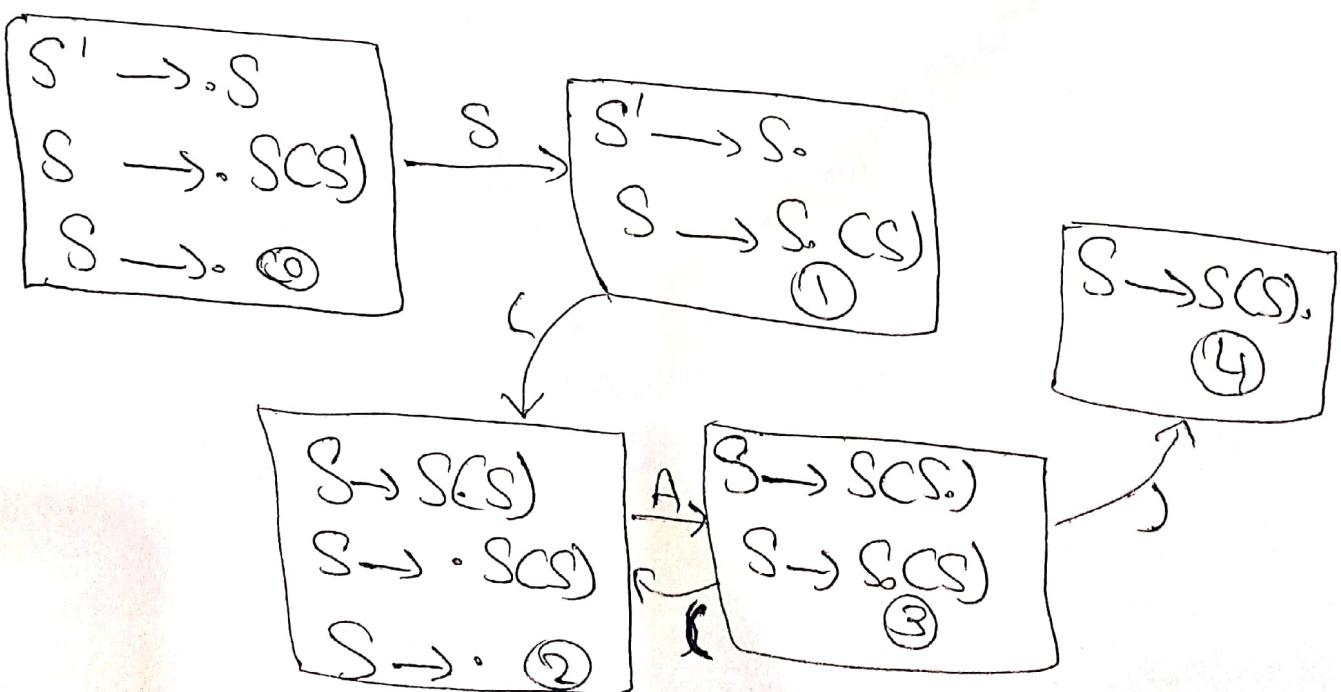
DFA of LALR(1) :-



Question 3:- $S \rightarrow SCS|E$

Part 1:-

a) DFA for LR(0) items.



b) SLR(1) Parsing Table:-

The following table uses the grammar rule
as $S \rightarrow SCS$ ①
 $S \rightarrow \epsilon$ - ②

State	Input			Goto
	C)	\$	A
0	γ_2	γ_2	γ_2	1
1	S_2		Accept	
2	γ_2	γ_2	γ_2	3
3	S_2	S_4		
4	γ_1	γ_1	γ_1	

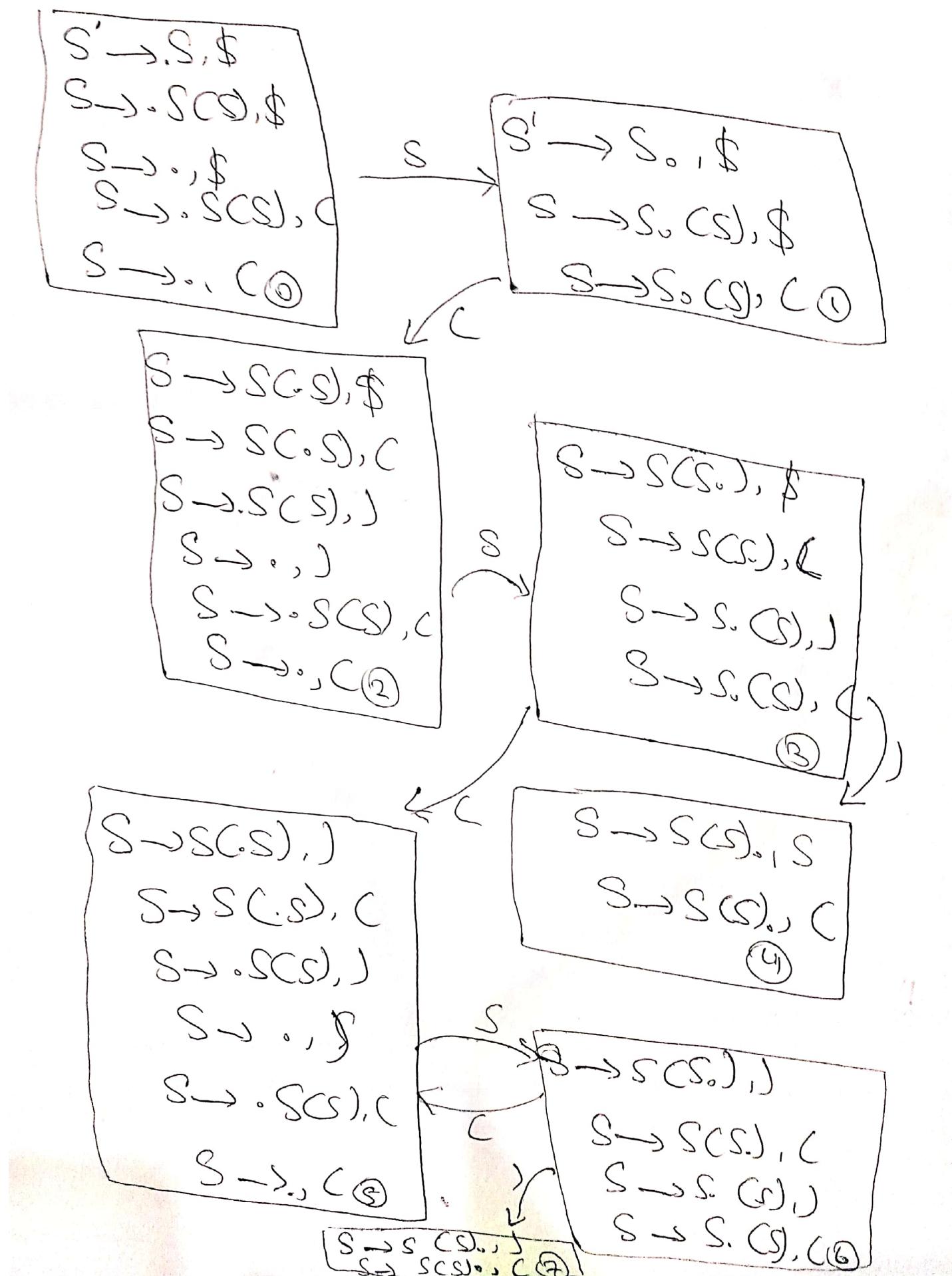
c)

Parsing Stack	Input	Action
\$0	C(C)J\$	reduce2
\$0A1	C(C)J\$	shift 2
\$0A1C2	C(C)J\$	reduce2
\$0A1C2A3	C(C)J\$	shift 2
\$0A1C2A3C2	J(C)J\$	reduce2
\$0A1C2A3C2A3	J(C)J\$	shift 4
\$0A1C2A3C2A3C2	J(J)\$	reduce1
\$0A1C2A3C2A3C2A3	C(J)\$	shift 2
\$0A1C2A3C2A3C2	J(J)\$	reduce2
\$0A1C2A3C2A3C2A3	J(J)\$	shift 4
\$0A1C2A3C2A3C2A3C2	J(\$)	reduce1
\$0A1C2A3C2A3C2A3C2A3	\$	shift 4
\$0A1C2A3C2A3C2A3C2A3	\$	reduce1
\$0A1C2A3C2A3C2A3C2A3	\$	Accept

d) The grammar is not an LRC(0) grammar since state 1 has both a shift and a reduce (accept) state.

Part 2:-

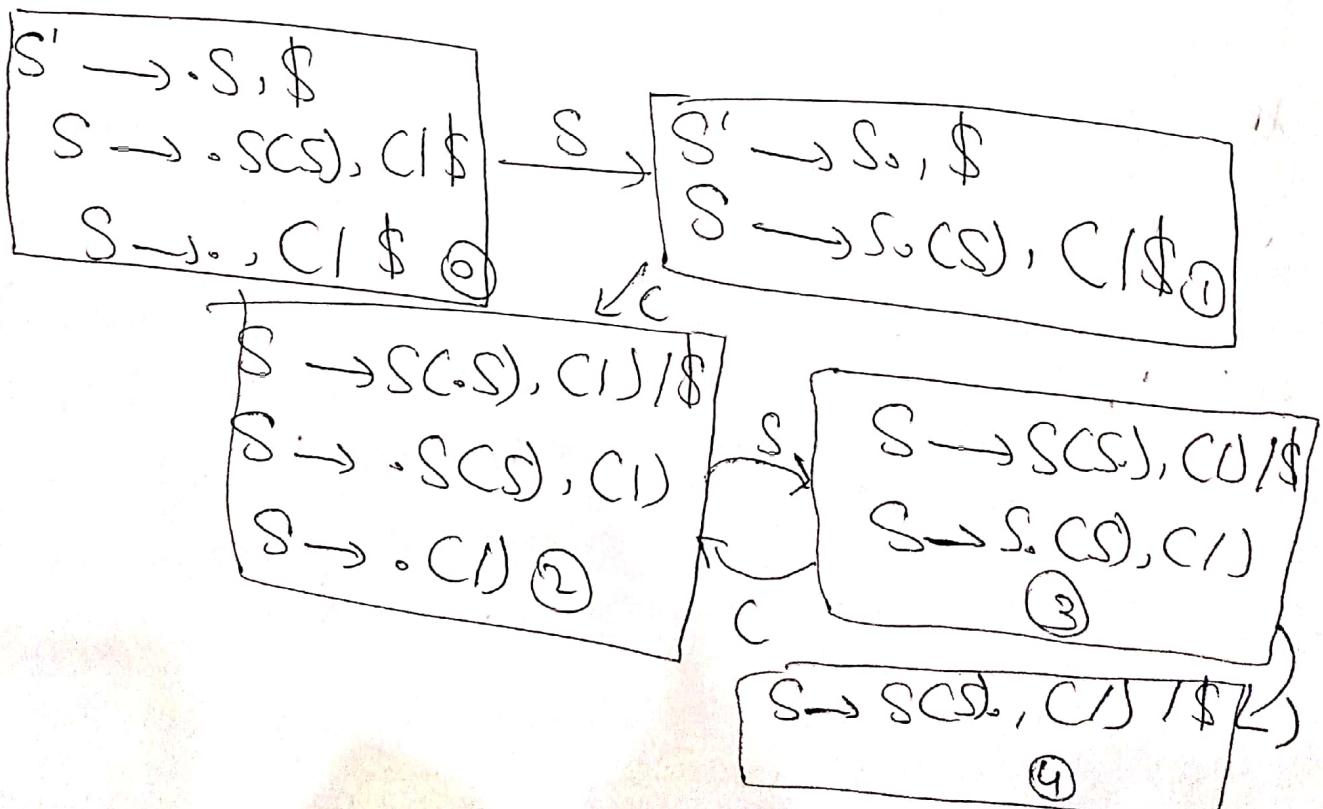
a) DFA for LR(1) items:-



b) LR(1) Parsing Table:

State	C	S	\$	Proto
0	γ_2		γ_2	1
1			Accept	
2	γ_2	γ_2		3
3	γ_3	γ_4		
4			γ_1	
5	γ_2	γ_2		6
6	γ_3	γ_7		
7	γ_1	γ_1		

c) DFA of LALR(1):-



d) LALR(1) Parsing Table:

State	Input			Final
	C)	\$	A
0	γ_2		γ_2	1
1	S_2		Accept	
2	γ_2	γ_2		3
3	S_2	S_4		
4	γ_1	γ_1	γ_1	

e) The only possible difference between the actions of an LRC(1) parser and an LALR(1) parser is that in the presence of errors, the LALR(1) parser may make some extra reductions before declaring errors. Comparison of tables of both parsers show that there are two situations in which the LALR(1) parser will make a reduction, while the LRC(1) and LRC(1) parsers are both in state 4 and the LRC(1) parser will declare error while LALR(1) will reduce by the rule $S \rightarrow SCS$. First then will declare error. This will happen for example

on the input C). The second case occurs when LRC1 is in state 7 and LALRC1 in state 4 and the next input is \$ in which case the LALRC1 again reduces by rule 1 before declaring error.

This will happen for example on the input CC).

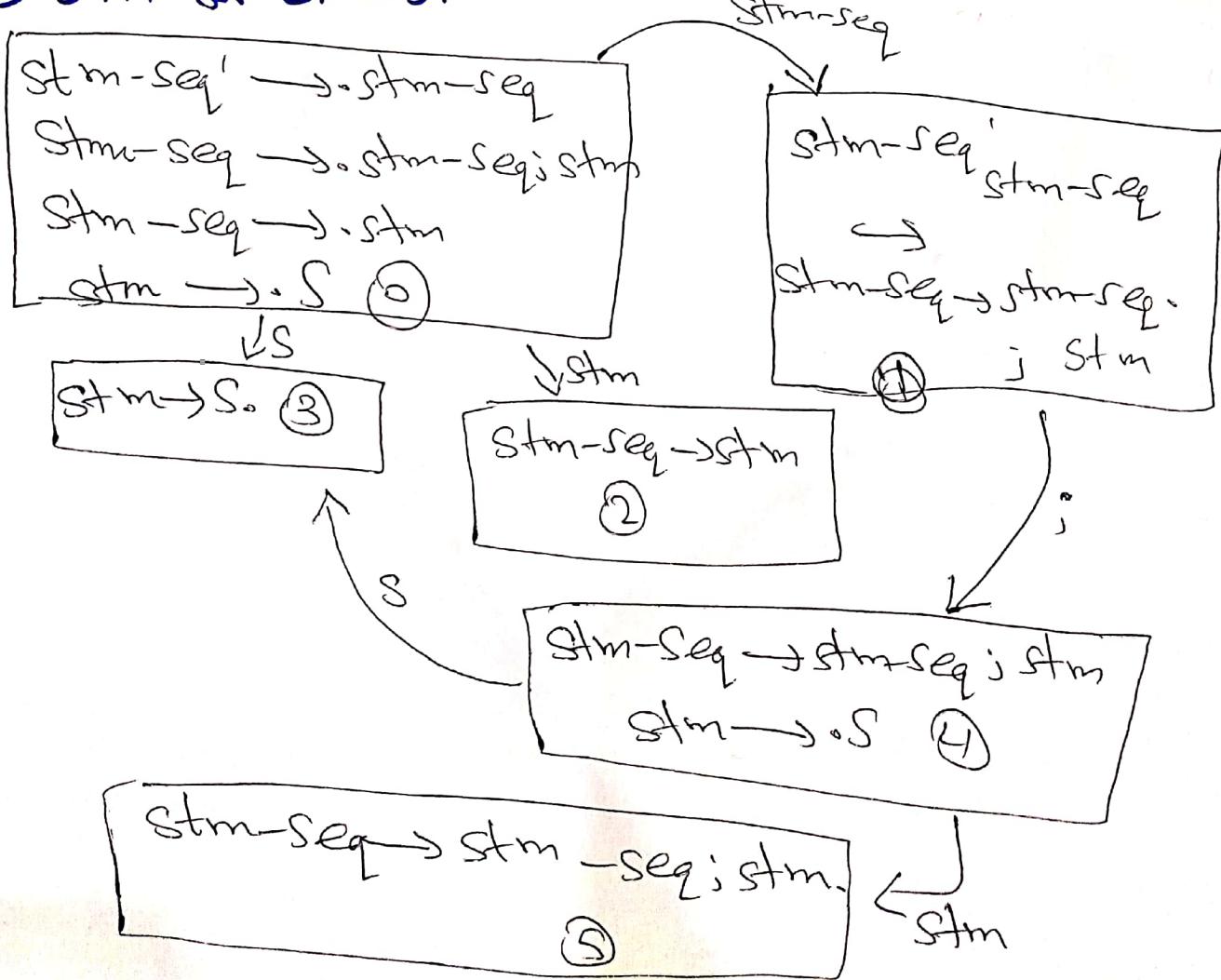
Question 4:-

$\text{Stmt-seq} \rightarrow \text{stmt-seq}; \text{stmt}$

$\text{Stmt} \rightarrow S$

Part 1:

a) DFA for LR(0):



b) SLR(1) Parsing Table:

The parsing table uses the grammar rule.

$$Stm-Seq \rightarrow Stm \text{ Seq} ; Stm \quad ①$$

$$Stm-Seq \rightarrow Stm \quad ②$$

$$\text{also } Stm \rightarrow S \quad ③$$

$$\text{Follow}(Stm-Seq) = \{\$, ;\}$$

$$\text{Follow}(Stm) = \{\$, ;\}$$

(with grammar 2 - line 2)

- concept of LR(0)

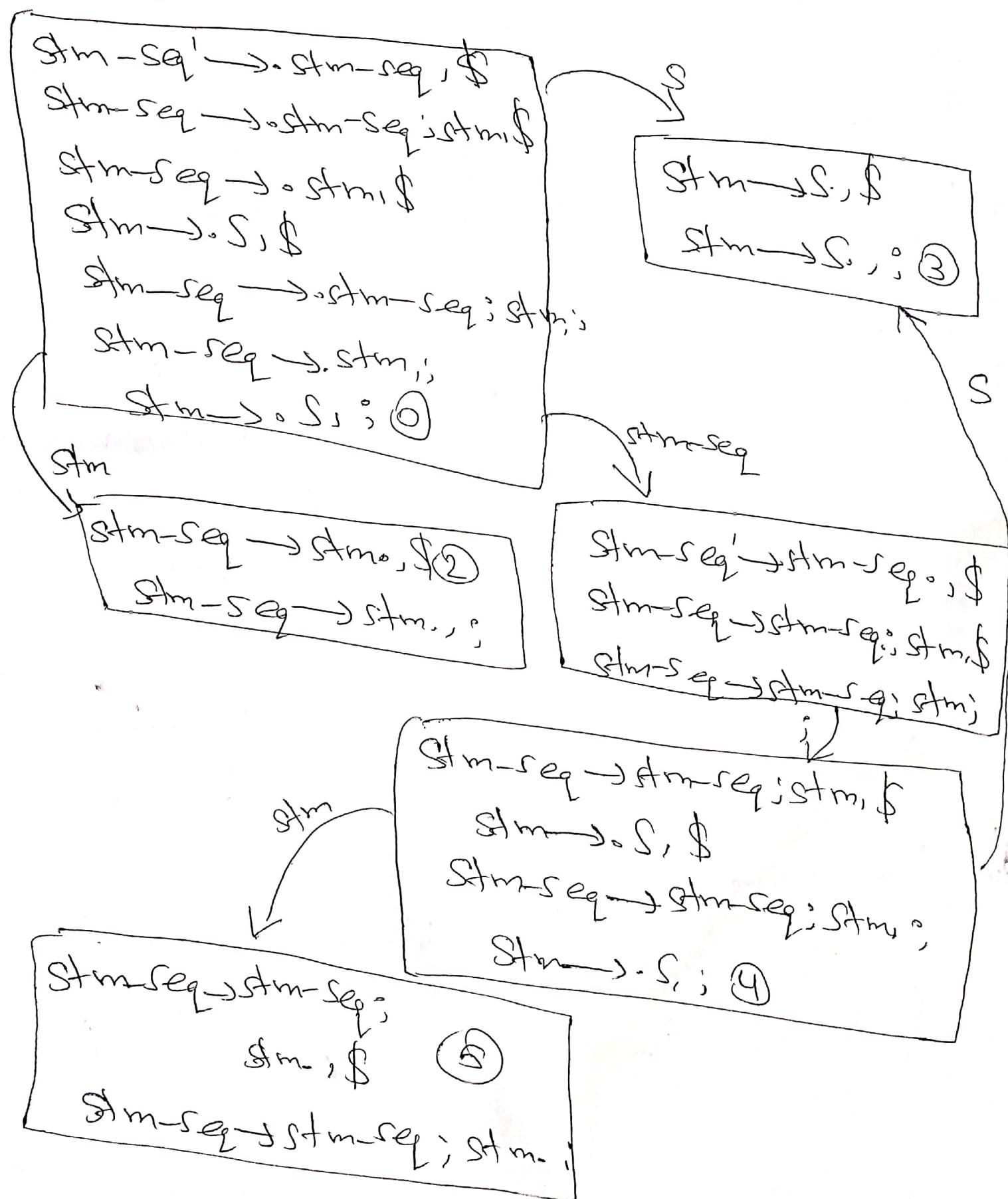
State	Input	Output	goto
0	S	;	Stm-Seq
0	S3		1
1	S4	Accept	
2	x2	x2	
3	x3	x3	
4	S3		5
5	x1	x1	

c) Stack	Input	Action
\$ 0	S; S; S \$	Shift 3
\$ 0 S 3	; S ; S \$	Reduce 3
\$ 0 stm 2	; S ; S \$	reduce 2
\$ 0 stm-seq 1	; S ; S \$	Shift 4
\$ 0 stm-seq 1 ; 4	S ; S \$	Shift 3
\$ 0 stm-seq 1 ; 4 ; 3	; S \$	reduce 3
\$ 0 stm-seq 1 ; 4 ; 3 ; 5	; S \$	reduce 1
\$ 0 stm-seq 1 ; 4 ; 3 ; 5 ; (; S \$	Shift 4
\$ 0 stm-seq 1 ; 4 ; 3 ; 5 ; (; S \$	Shift 3
\$ 0 stm-seq 1 ; 4 ; 3 ; 5 ;)	; \$	reduce 3
\$ 0 stm-seq 1 ; 4 ; 3 ; 5 ;)	; \$	reduce 1
\$ 0 stm-seq 1	\$	Accept

d) The grammar is not LR(0) grammar
 since state 1 has both a shift and a reduce (accept) action.

Part 2:

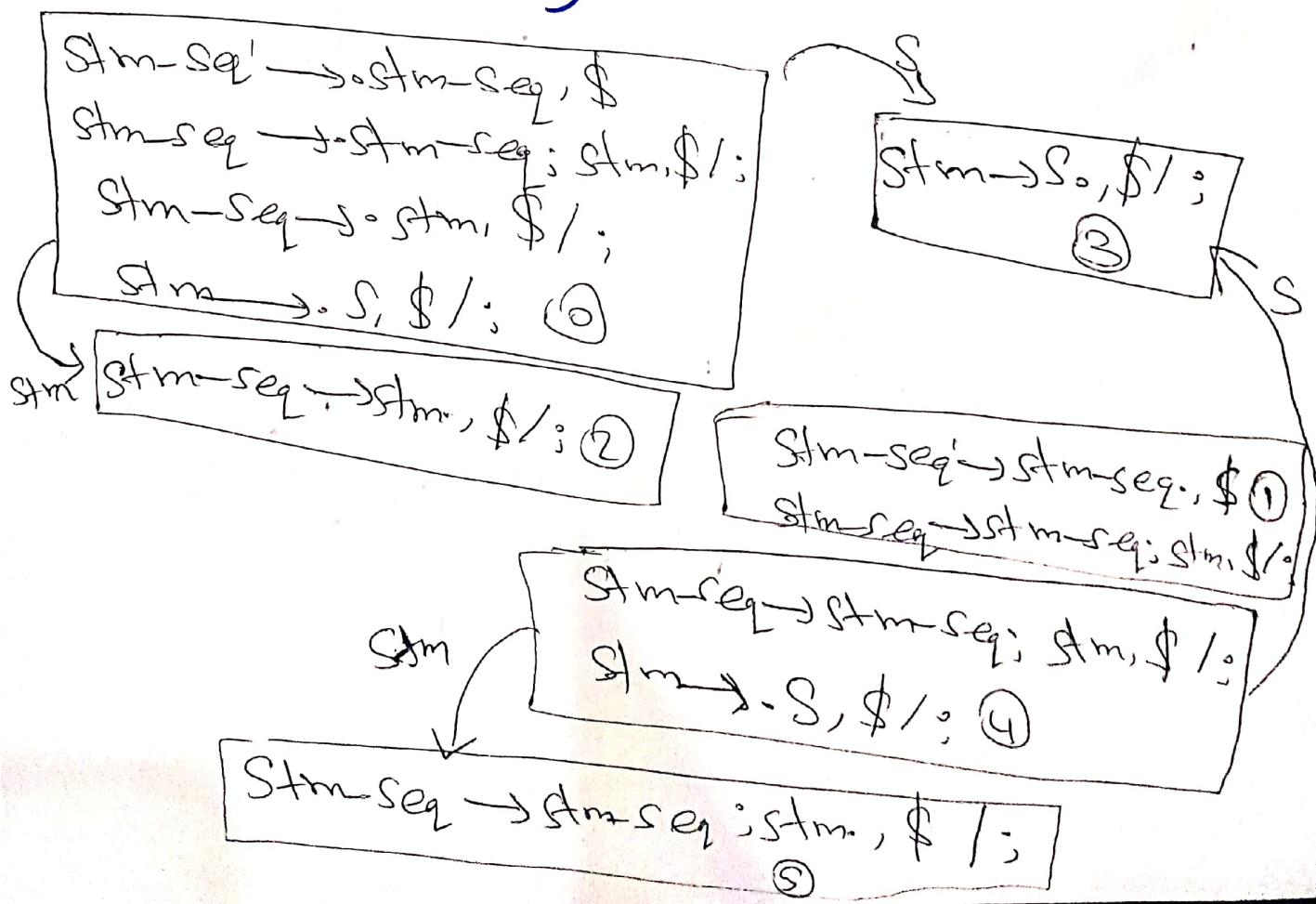
a) DFA for LRCU:-



b) LRC(1) Parsing Table

State	Input			Go to	
	S	:	\$	Stm-Seq	Stm
0	S3			1	2
1	S4	Accept			
2	x2		x2		
3	x3		x3		
4	S3				
5	x1	x1			

c) DFA of LALR(1)

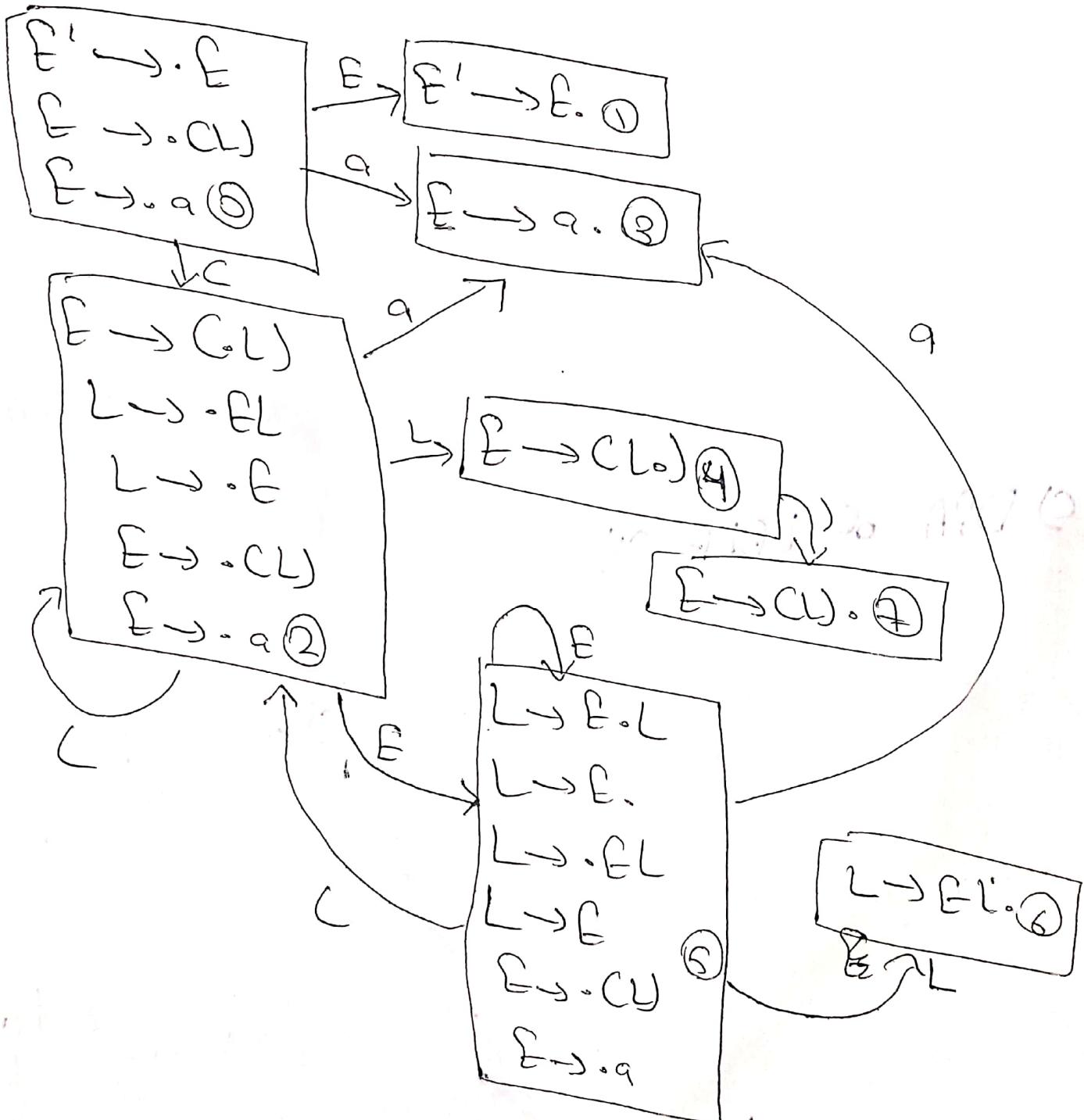


Question # 5:

$$E \rightarrow CL \mid a$$
$$L \rightarrow EL \mid E$$

Part 1:-

a) DFA of LRCQ :-



b) SLR(1) Parsing Table

State	Input				Goto	
	()	a	\$	E	L
0	S2		S3		1	
1						
2	S2		S3	Accept		
3	γ_2	γ_2	γ_2	γ_2	S	4
4		γ_7				
5	S2	γ_4	S3			
6		γ_3				
7	γ_1	γ_1	γ_1	γ_1		

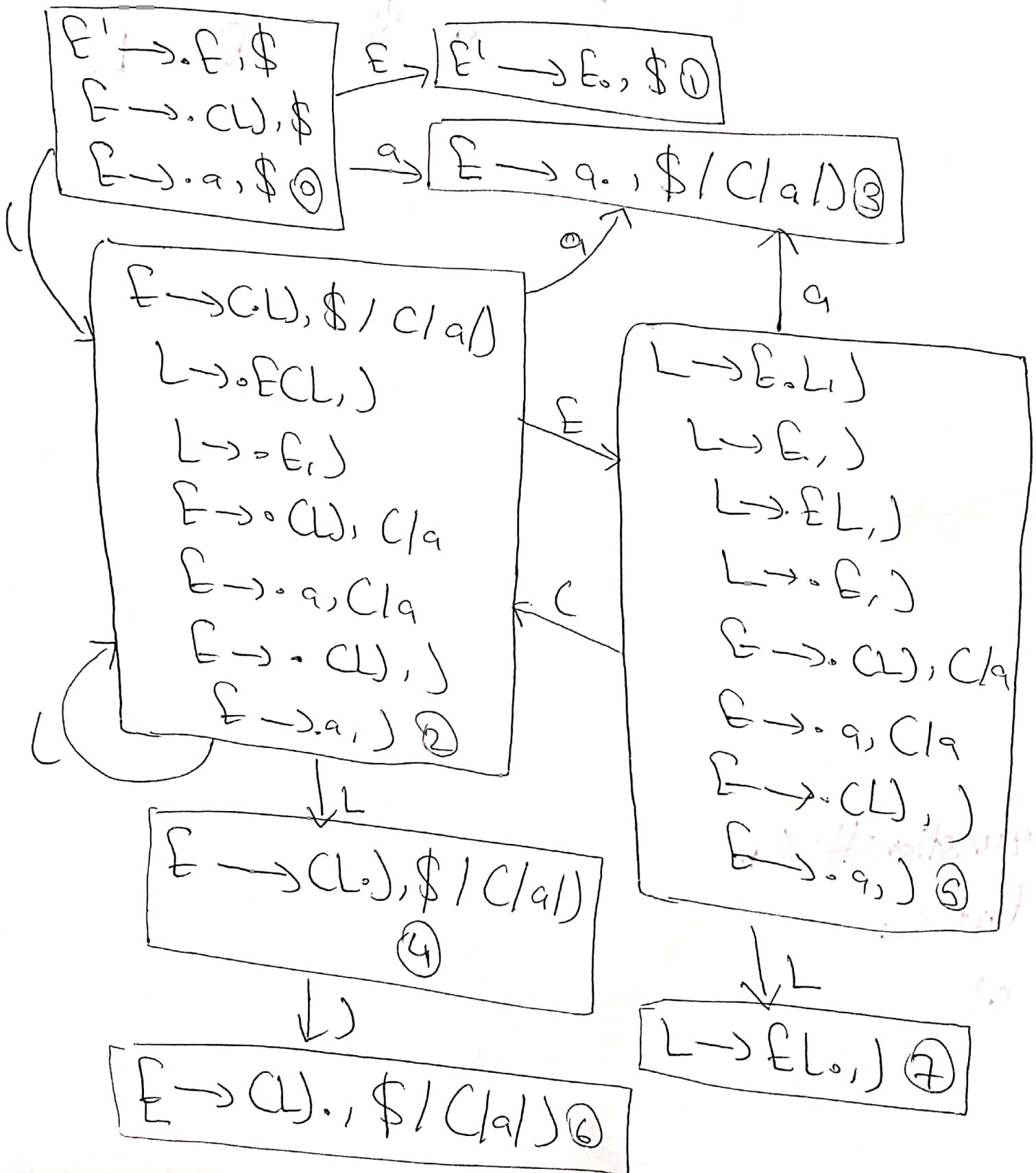
c)

Stack	Input	Action
\$ 0	((a)a(aa))\$	shift 2
\$ 0C2	(a)a(aa))\$	shift 2
\$ 0C2C2	a)a(aa))\$	shift 3
\$ 0C2C2a3)a(aa))\$	reduce2
\$ 0C2C2E5)a(aa))\$	reduce4
\$ 0C2C2E4)a(aa))\$	shift 7

\$ 0C2(2L4)7	a(a))\$	reduced
\$ 0C2ES	a(a))\$	shift 3
\$ 0C2ES a3	(aa))\$	reduced
\$ 0C2ES ES.	(aa))\$	shift 2
\$ 0C2ES ESC2	aa))\$	shift 3
\$ 0C2ES ESC23	a))\$	reduce 2
\$ 0C2ES ESC2ES)\$	shift 3
\$ 0C2ES ESC2ES a3)\$	reduce 2
\$ 0C2ES ESC2ESL6)\$	reduce 4
\$ 0C2ES ESC2L4)\$	reduce 3
\$ 0C2ES ESC2L4)7)\$	shift 7
\$ 0C2ES ESCS)\$	reduce 1
\$ 0C2ES ESCL6)\$	reduce 4
\$ 0C2ES L6)\$	reduce 3
\$ 0C2L4)\$	reduce 3
\$ 0C2L4)7)\$	shift 7
\$ 0E1)\$	reduce 1
		Accept.

Part 2:

d) DFA of LALR(1):



State	Input				Goto	
	()	a	\$	F	L
0	S2		S3		1	
1					Accept	
2	S2		S3		5	4
3	x2	x2	x2	x2		
4		S6				
5	S2	x4	S3		5	7
6	x1	x1	x1	x1		
7		x3				

Question # 6 :-

Part 1:-

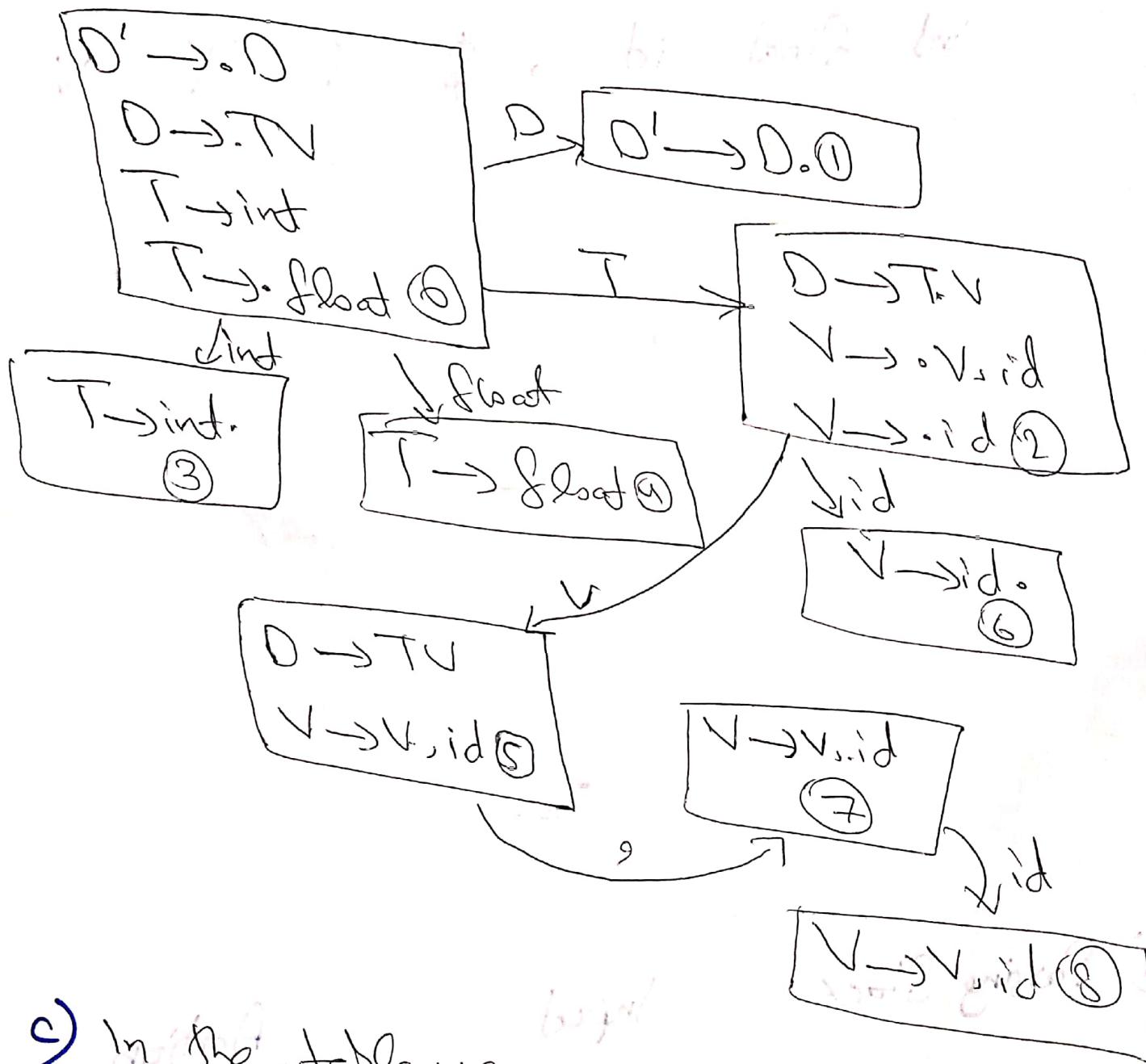
a) Right recursion cause the passing stack to grow unnecessarily so we rewrite the grammar.

$$D \rightarrow T V$$

$$T \rightarrow \text{int} \mid \text{float}$$

$$V \rightarrow V, \text{id} \mid \text{id}$$

b) DFA & LR(0)



c) In the table we use the numbering of rules as;

- ① $D \rightarrow TV$
- ② $T \rightarrow \text{int}$
- ③ $T \rightarrow \text{float}$
- ④ $V \rightarrow V.\text{id}$
- ⑤ $V \rightarrow \text{id.}$

SLR(1) Parsing Table

State	Input					Goto		
	int	float	id	,	\$	D	T	V
0	S3	S4		S3		1	2	
1					Accept			
2			S6					5
3			x2					
4			x3					
5				S7	x1			
6				x5	x5			
7			x8		x4			
8				x4	x4			

d) Parsing Stack

Parsing Stack	Input	Action
\$0	int x,y,z \$	shift 3
\$0:int3	x,y,z \$	reduce 2
\$0T2	x,y,z \$	shift 6
\$0T2:id6	x,y,z \$	reduce
\$0T2VS	x,y,z \$	shift 7
\$0T2VS,T	x,y,z \$	shift 8
\$0T2VS,T:id8	x,y,z \$	reduce 4 shift 7
\$0T2VS	x,y,z \$	

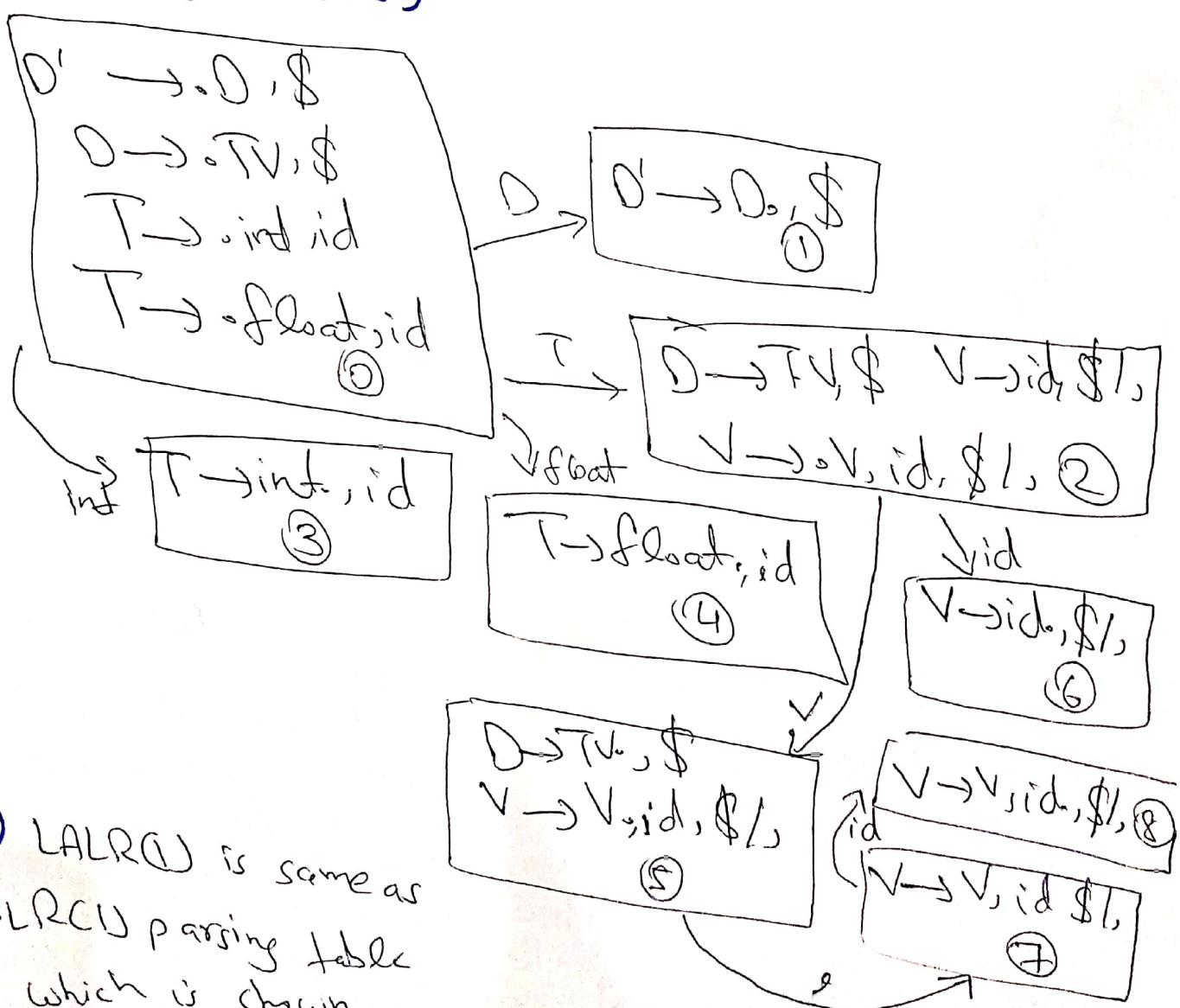
\$ OT2VS,7
\$ OT2VS,7:d8
\$ OT2VS
\$ OT2VS,7
\$ OT2VS,7:d8
\$ OT2VS
\$ ODI

g. 2 \$ 2 \$ 2 \$ 2 \$ 2 \$ 2 \$

- Shift 8
- reduce 4
- Shift 7
- Shift 8
- reduce 4
- reduce 1
- Accept

Part 2:

a) DFA of LALR(1)



b) LALR(1) is same as SLR(1) parsing table which is shown

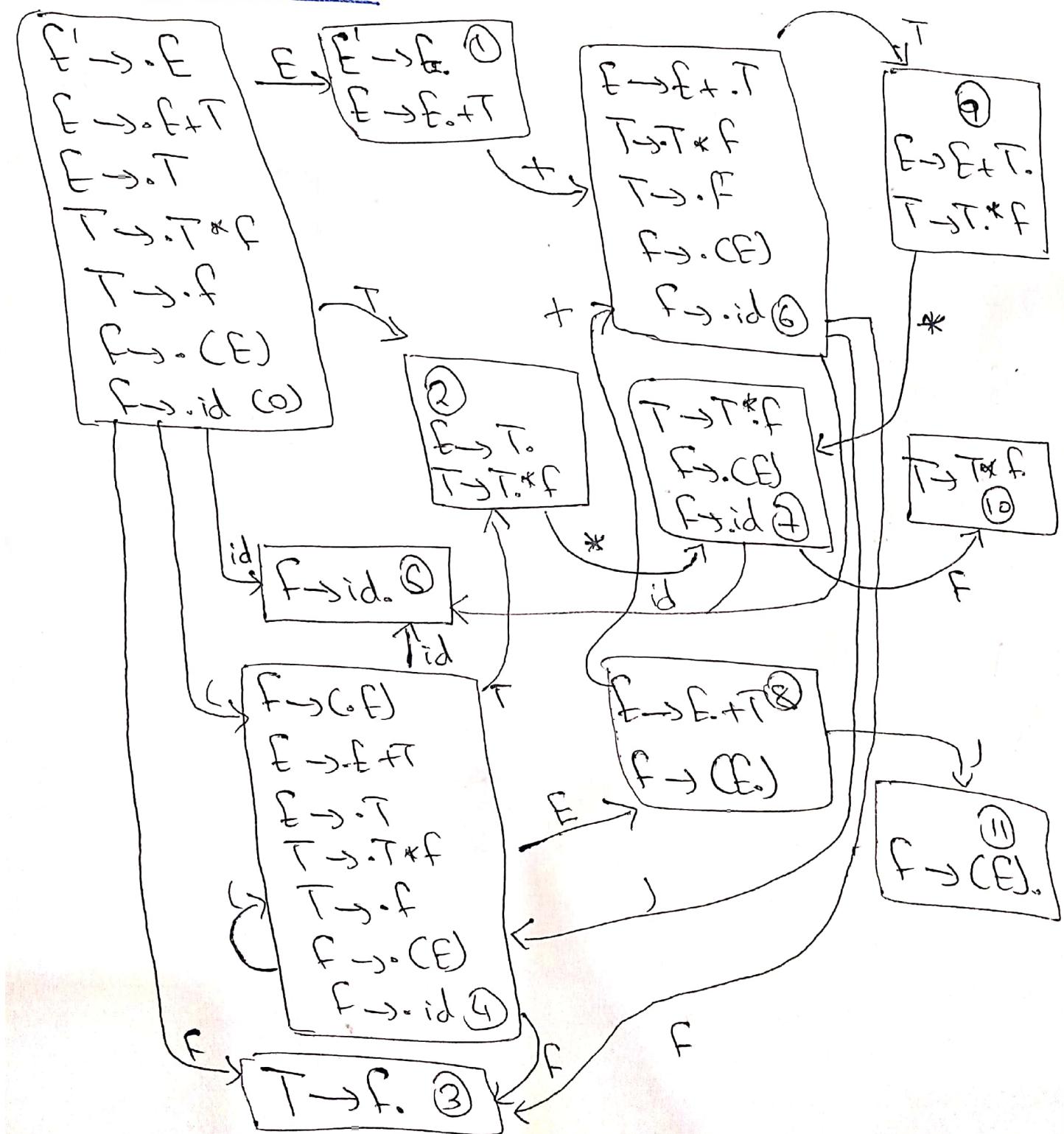
Question #7:

$$E \rightarrow E + T \mid T$$

$$T \rightarrow T^* F \mid F$$

$$F \rightarrow (CE) \mid id$$

a) LRC0 automaton:



b) SLR(1) Parsing Table:

State	Action							Goto		
	id	+	*	C)	B	E	T	F	
0	S5			S4			1	2	3	
1		S6				accept				
2		S2, S7			S2	S2	.	.		
3		S4	S4		S4	S4	.	.		
4	S5			S4	.		8	2	3	
5		S6	S6		S6	S6	.	.		
6	S5	.		S4	.			9	3	
7	S5	.		S4	.				10	
8		S6	.		S11	.				
9		S1	S7		S1	S1	.	.		
10		S3	S3	.	S3	S3	.	.		
11		S5	S5		S5	S5	.	.		

c)

Stack	Input	Actions
\$0	i.d * id + id \$	shift 5
\$0id\$	* id + id \$	reduce6
\$0f3	* id + id \$	reduce4
\$0f2	* id + id \$	shift7
\$0T2*7	id + id \$.	shift5
\$0T2*7:id\$	+ id\$	reduce6
\$0T2*7:f10	+ id\$	reduce3
\$0T2	+ id\$	reduce2
\$0E1	+ id\$	shift6
\$0E1+6	id\$	shift5
\$0E1+6:id\$	\$	reduce6
\$0F1+6f3	\$	reduce4
\$0E1+6f9	\$	reduce1
\$0E1	\$	Accept

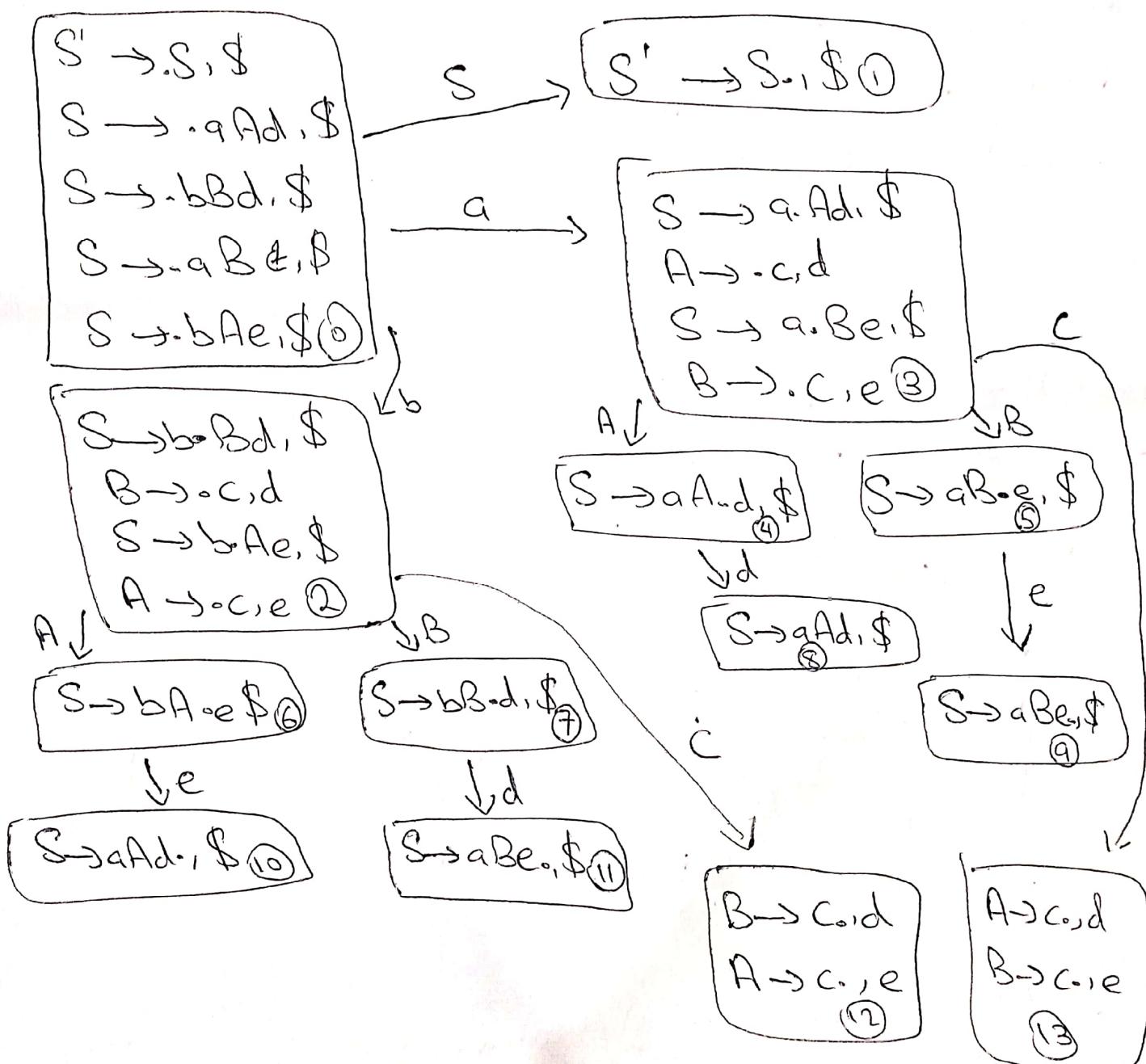
Question #8..

i) $S' \rightarrow S$

$$S \rightarrow aAd \mid bBd \mid aBe \mid bAe$$

$$A \rightarrow C$$

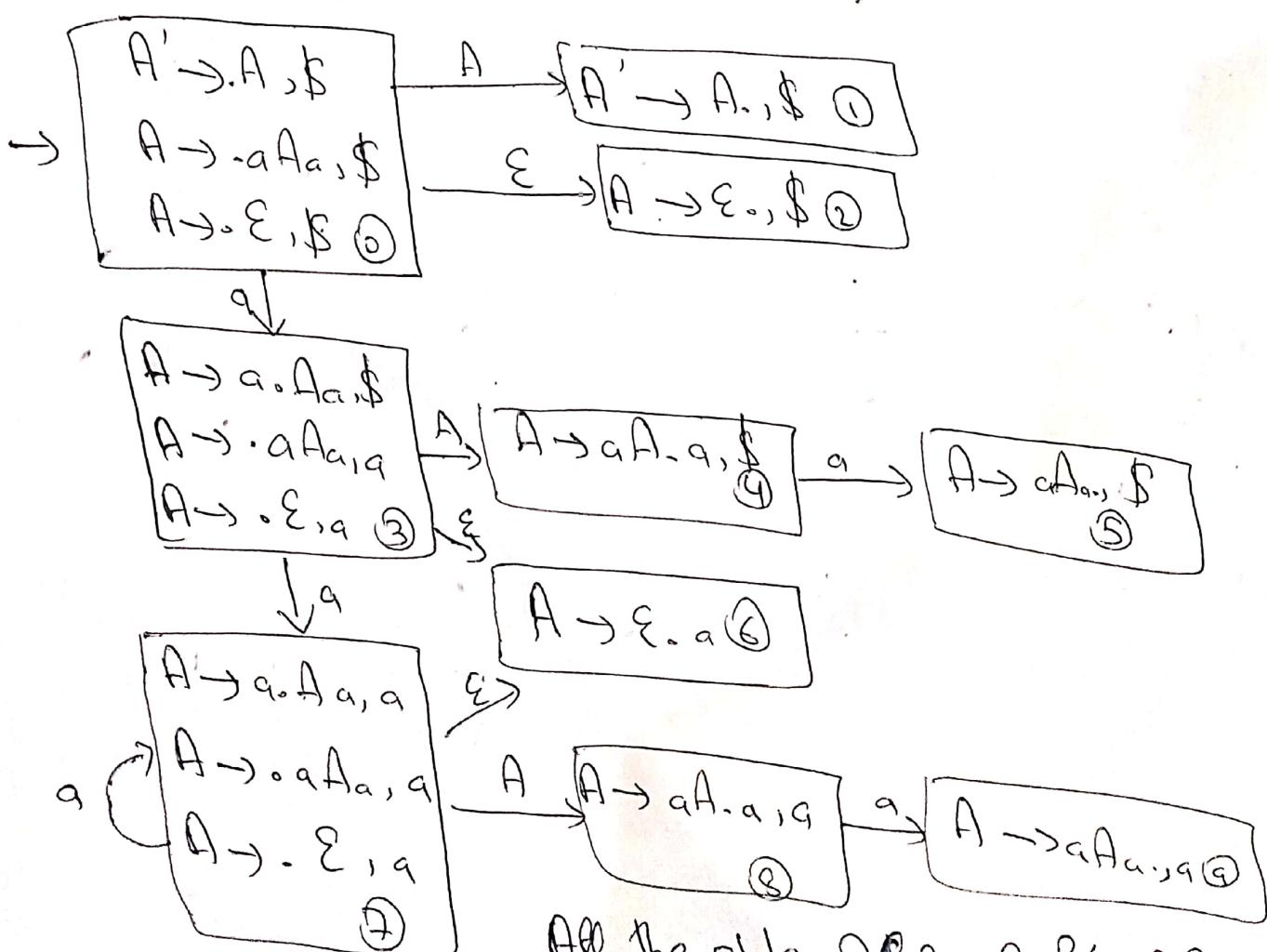
$$B \rightarrow C$$



From this DFA it can be seen that there are no parsing conflicts, so this grammar is LRC(1). In particular the reductions by $A \rightarrow C$ and $B \rightarrow C$ in states 12 and 13 occurs for different lookaheads. However, these two states would be combined in the DFA of LALRC(1) items (since they have the same set of LR(0) items) and then a reduce-reduce parsing conflict results, since reductions by both $A \rightarrow C$ and $B \rightarrow C$ would be indicated for lookaheads d and e. Thus, the Grammar is Not LALRC(1).

ii)

Part a)



All the state 0, 2, 3 & 6, 7
Contain shift reduce error.

Part b:-

The grammar is ambiguous since it generates same parse tree for all inputs. All unambiguous grammars are not LR(0) even if all LR(k) grammars are unambiguous.

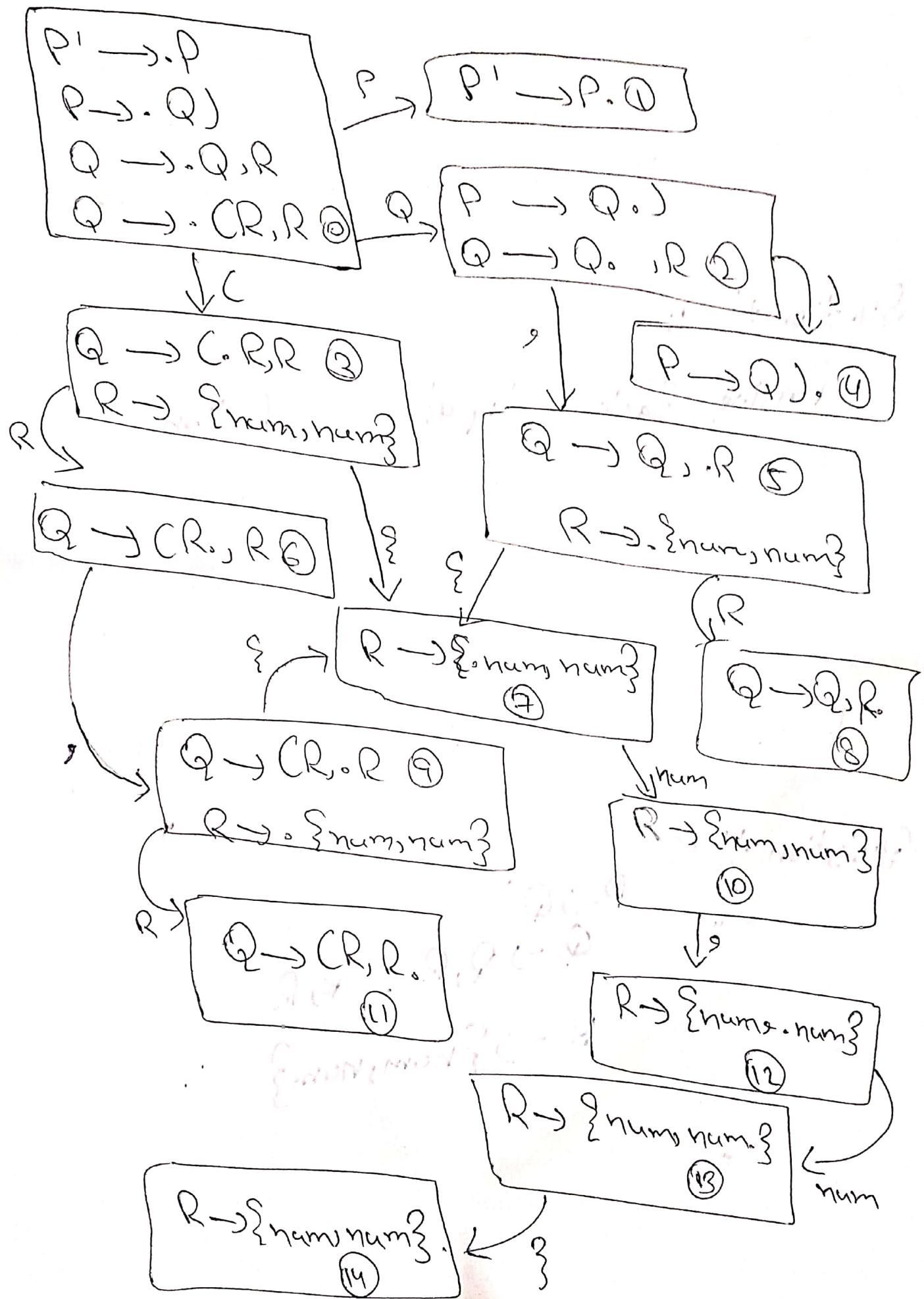
Question # 9:-

Parsing Stack	Input	Action
\$ 0	C * 2 \$	Shift 6
\$ 0 C 6	* 2 \$	Error; push exp, goto 10
\$ 0 C 6 exp 10	* 2 \$	Error;
\$ 0 C 6 exp 10 * 14	2 \$	Shift 14; reduce 8

Question # 10

$$\begin{aligned}
 P &\rightarrow Q \\
 Q &\rightarrow Q, R \mid CR, R \\
 R &\rightarrow \{ \text{num}, \text{num} \}
 \end{aligned}$$

DFA for LR(0)



LR(0) Parsing Table

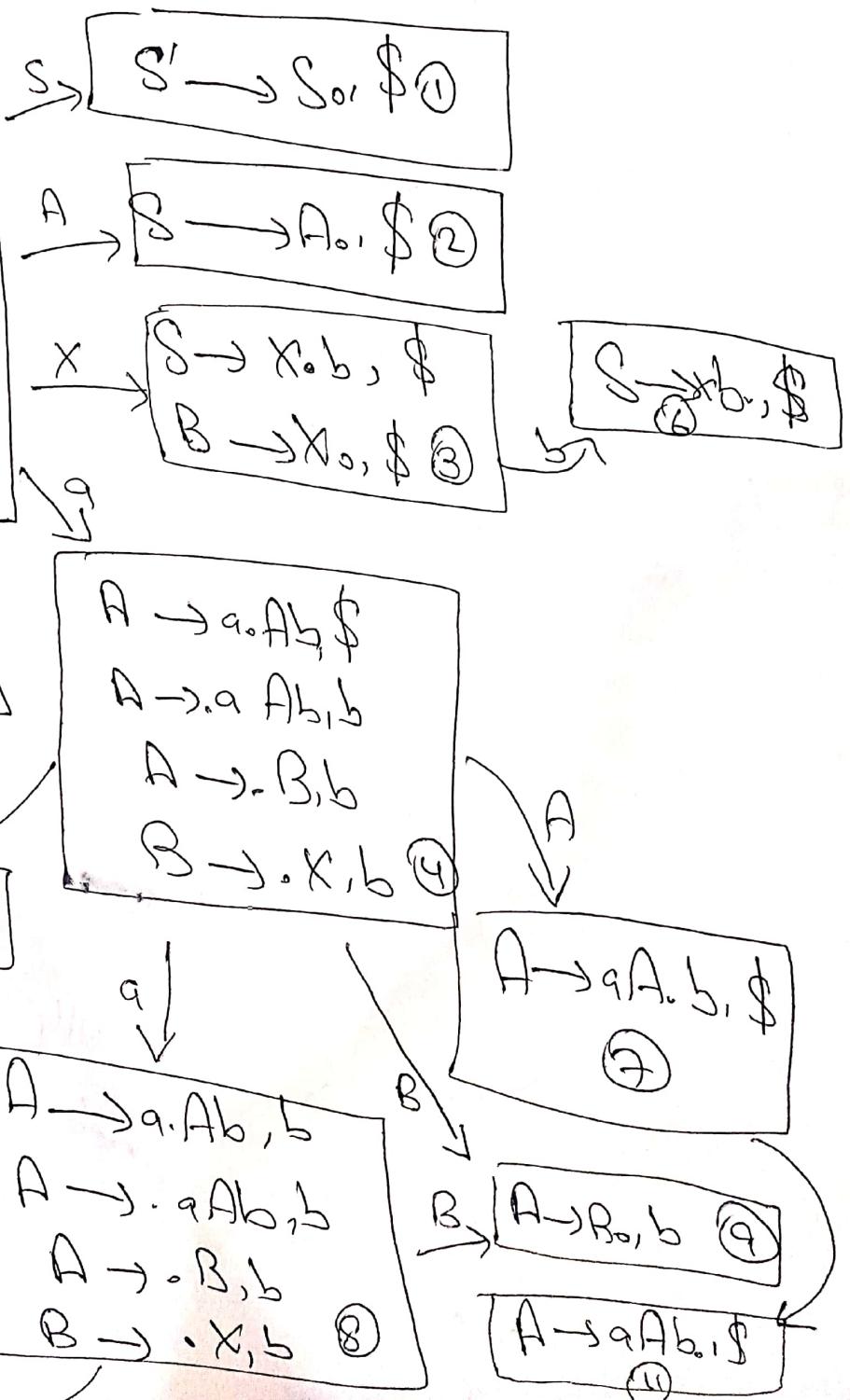
State	Input								Action	
	()	,	num	{	}	\$	P	Q	R
0	3							1	2	
1							*			
2	S4	SS								
3					S7					6
4	γ₁	γ₁	γ₁	γ₁	γ₁	γ₁	γ₁			
5					S7					8
6		S9								
7			S10							
8	γ₂	γ₂	γ₂	γ₂	γ₂	γ₂	γ₂			
9				S7						11
10		S12								
11	γ₃	γ₃	γ₃	γ₃	γ₃	γ₃	γ₃			
12			S13	8						
13						S14				
14	γ₄	γ₄	γ₄	γ₄	γ₄	γ₄	γ₄			

Question # 11

$S \rightarrow A$
 $S \rightarrow xb$
 $A \rightarrow aAb$
 $A \rightarrow B$
 $B \rightarrow X$

a) DFA for LRC1 :-

$S' \rightarrow S, \$$
 $S \rightarrow A, \$$
 $S \rightarrow X, b, \$$
 $A \rightarrow aAb, \$$
 $A \rightarrow B, \$$
 $B \rightarrow X, \$$ ⑥



b) LRCI) Parsing Table

State	Input				Goto		
	a	b	x	\$	S	A	B
0	s4		s3		1	2	3
1					Accept		
2					γ_1		
3		s6			γ_5		
4	s8		s10			7	9
5					γ_4		
6					γ_2		
7		s11					
8	s8		s10			7	9
9		γ_4					
10		γ_5					
11				γ_3			

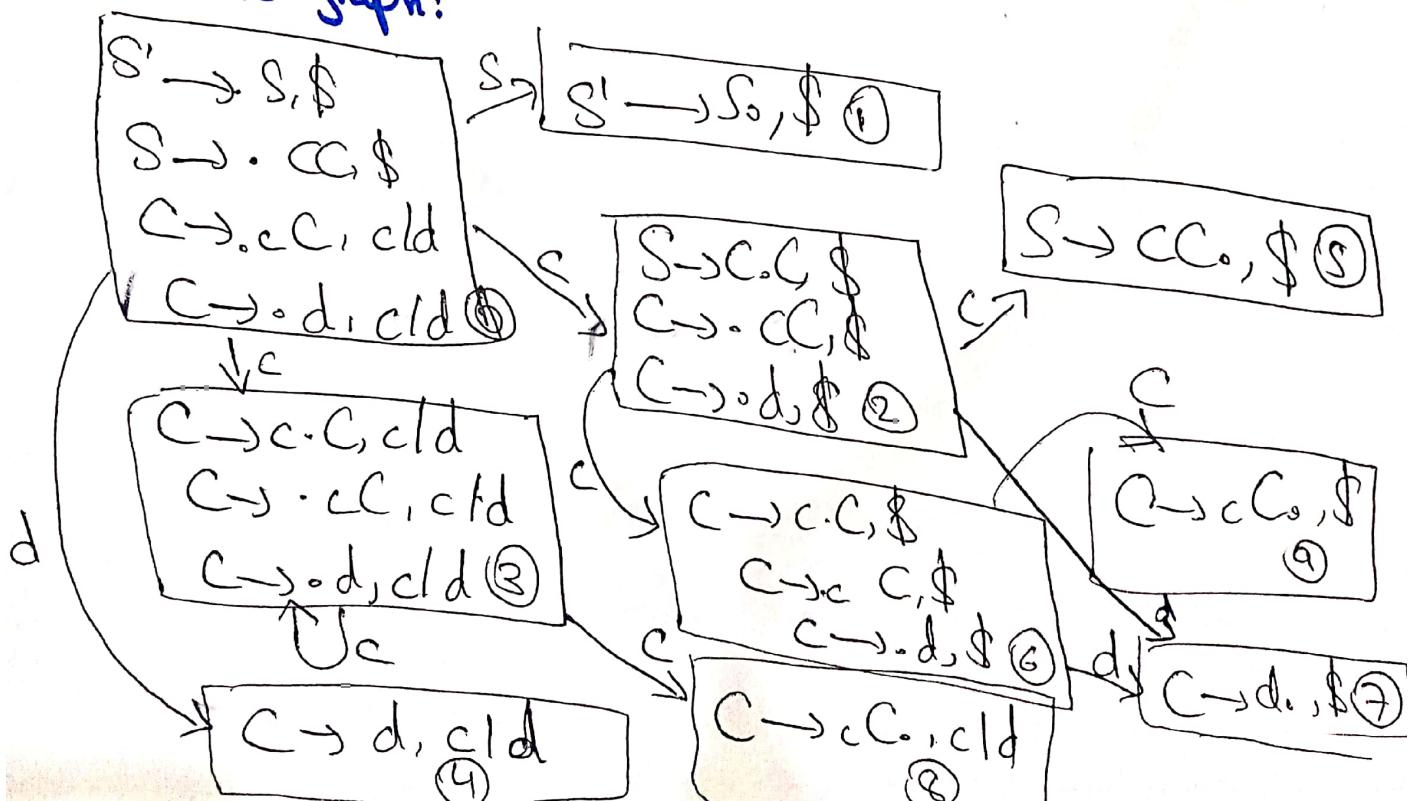
d)

Stack	Input	Action
\$0	axb\$	Shift 4
\$0a4	xb\$	Shift 10
\$0a4b0	b\$	reduces
\$0a4B9	b\$	reduce 4
\$0a4A7	b\$	Shift 11
\$0a4Ab11	\$	reduces
\$0A2	\$	reduce 1
\$0S1	\$	Accept

Question 12:

$$\begin{aligned} S' &\rightarrow S \\ S &\rightarrow CC \\ C &\rightarrow CC \mid d \end{aligned}$$

a) GOTO graph:



b) Canonical Parsing Table

State	Action			Goto	
	c	d	\$	s	c
0	S3, S4			1	2
1			Accept		
2	S6	S7			5
3	S3	S4			8
4	γ3	γ3			
5			γ1		
6	S6	S7			
7			γ3		
8	γ2	γ2			
9			γ2		

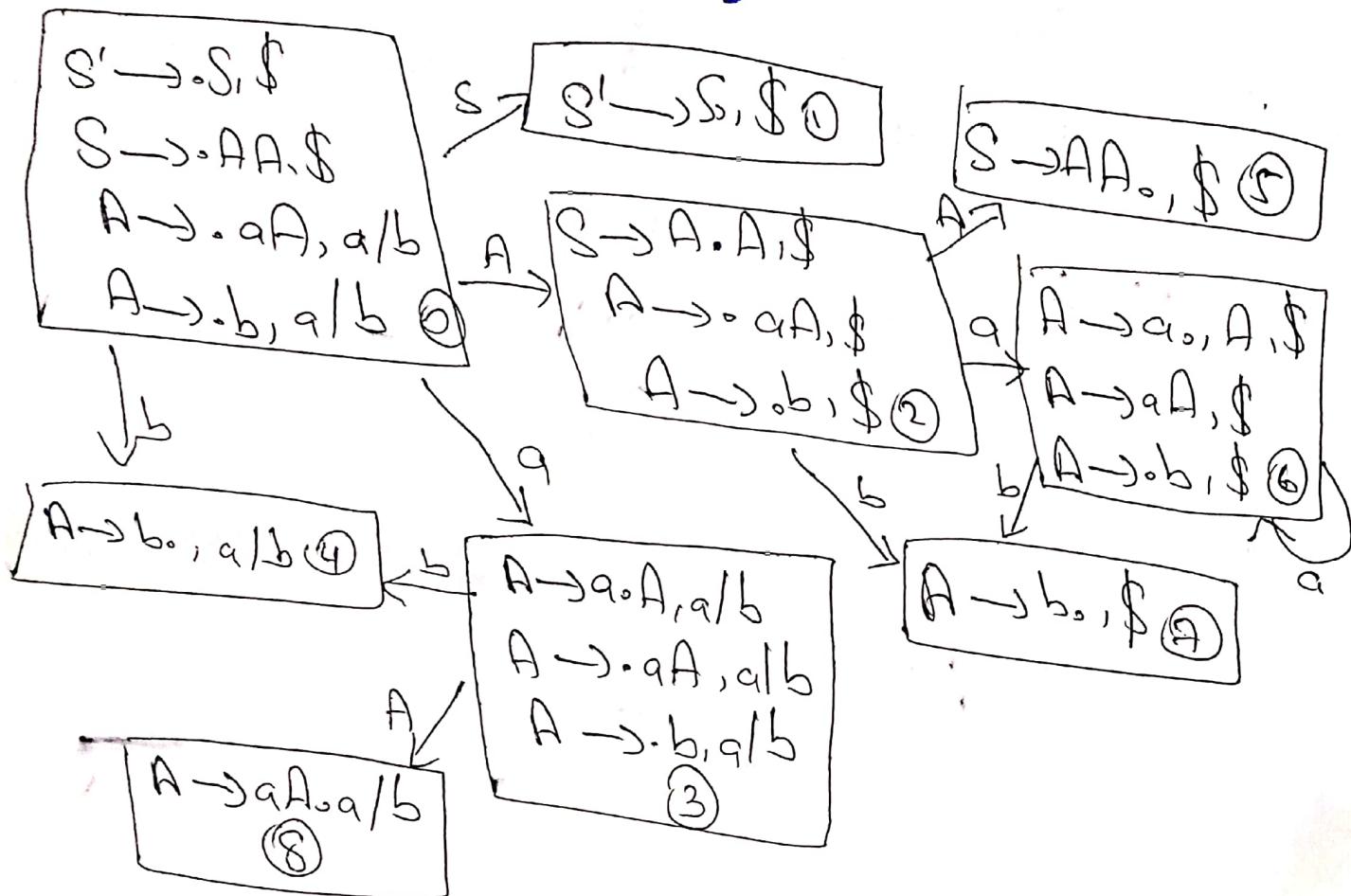
c) LALR Parsing Table:

State	Action			Goto	
	c	d	\$	s	c
0	S36	S47		1	
1			Accept		
2	S36	S47			5
36	S36	S47			
47	γ3	γ3	γ3		
5			γ1		
89	γ2	γ2	γ2		

Question #13 $S \rightarrow AA$

$A \rightarrow aA/b$

i) DFA of canonical CLR CI

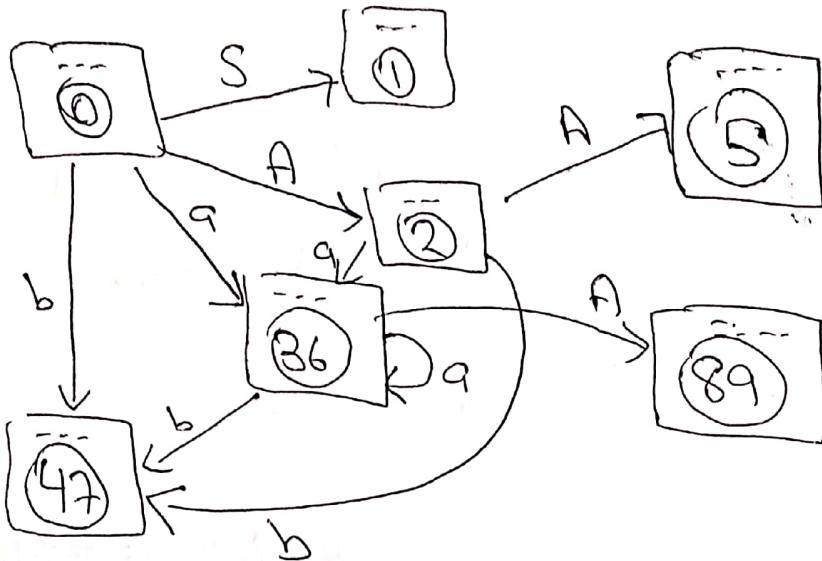


ii) CLR CI Parsing Table:

States	Input			Goto	
	a	b	$\$$	S	A
0	s_3	s_4		1	2
1			Accept		
2	s_6	s_7			
3	s_3	s_4			
4	s_3	s_3			
5			s_1		
6	s_6	s_7			
7			s_3		
8	s_2	s_2			
9			s_2		

iii) DFA of LALR(1)

Merging the same states from the DFA of CLR(1) we have



iv) LALR(1) Parsing Table:-

States	Input			Goto	
	a	b	\$	S	A
0	S36	S47		1	2
1			Accept		
2	S36	S47			5
36	S36	S47			89
47	γ3	γ3	γ3		
5			γ1		
89	γ2	γ2	γ2		

Question #14:

$$\text{i) } S \rightarrow A_a A_b \mid B_b B_a$$

$$A \rightarrow \epsilon$$

$$B \rightarrow \epsilon$$

"ab" and "ba" can be determined by "a" and "b" hence S is LL(1). In SLR, consider state 0 which has $S \rightarrow \cdot A_a A_b, S \rightarrow \cdot B_b B_a, A \rightarrow \epsilon, B \rightarrow \epsilon$. When we reduce " ϵ " we can't decide reduce to A or B, this is a reduce-reduce conflict, hence S is not SLR(1).

$$\text{ii) } S \rightarrow S A A$$

$$A \rightarrow a$$

$$S \rightarrow S A A \Rightarrow S \rightarrow S a a$$

S is infinite sequence of "a" we can't determine how many "a" when we meet "a", S is not LL(1).

On the other hand, we can construct the SLR table with no conflicts hence S is SLR(1).

States	Input		Goto	
	a	\$	S	A
0	S3		1	2
1	S3			
2	γ_1	γ_1		
3	γ_2	γ_2		
4		a		

Question # 15:

$$\Rightarrow S \rightarrow Aa \mid bAa \mid dc \mid bdg$$

$$A \rightarrow d$$

SLR Table

States	Input					Proto	
	a	b	c	d	\$	S	A
0		S3		S4		1	2
1					accept		
2	S5						
3				S7			6
4	85		88 85				
5						81	
6		89					
7	81 85		85				
8					83		
9					82		
10					84		

There are shift-reduce conflicts, this grammar is not SLR(1).

Because when we meet "d" we can't decide whether to reduce A or shift ie $(S \rightarrow dc \mid bdg)$

LALR Table

	a	b	c	d	\$	S	A
0					S4	1	2
1						accept	
2	S5						
3				S7			6
4	X5		S8				
5					X1		
6			S9				
7	S10		X5				
8					X3		
9					X3		
10					X3		

No conflicts the grammar is LALR(1).

ii) $S \rightarrow Aa \mid bAc \mid Bc \mid bBa$

$A \rightarrow d$

$B \rightarrow d$

LR Table

State	a	b	c	d	\$	s	A	B
0		s_3		s_5			1	2
1						accept		
2		s_6						
3					s_9		7	8
4				s_{10}				
5	γ_5		γ_6					
6						γ_1		
7			s_{11}					
8		s_{12}						
9		γ_6	γ_5					
10				γ_3				
11				γ_2				
12				γ_4				

No. conflict grammar is LRC1)

LALR Table:

State	a	b	c	d	\$	S	A	B
0		s3		s5		1	2	4
1						accept		
2		s6						
3					s5		7	8
4				s9				
5	(s5 s6)	(s5 s6)						
6					x ₁	y ₁		
7			s10					
8	s11							
9					y ₃			
10					y ₂			
11					y ₄			

reduce-reduce conflict \Rightarrow not LALR(1)