Problem 1

(i) The given grammar is not LL(1) because

Left Recursion

Type → Type *

Common Prefix

ArgList → Type id, ArgList
ArgList → Type id

(ii) We transform the grammar by removing left recursion and common prefix

Function → Type id (Arguments)
Type → id Type'
Type' → * Type'
[redacted]
Type' → ∈
Arguments → ArgList
Arguments → ∈
ArgList → Type id ArgList'
ArgList' → , ArgList
ArgList' → ∈

(iii)

FIRST (Function) = {id}
FIRST (Type) = {id}
FIRST (Type') = {ϵ, *}
FIRST (Arguments) = {ϵ, id}
FIRST (ArgList) = {id}
FIRST (ArgList') = {, , ϵ}

FOLLOW (Function) = {$}
FOLLOW (Type) = {id}
FOLLOW (Type') = {id}
FOLLOW (Arguments) = {)}
FOLLOW (ArgList) = {)}
FOLLOW (ArgList') = {)}

(iv)

FIRST$^+$ (Function → Type id (Arguments)) = {id}
FIRST$^+$ (Type → id Type') = {id}
FIRST$^+$ (Type' → * Type') = {*}
FIRST$^+$ (Type' → ϵ) = {id}
FIRST$^+$ (Arguments → ArgList) = {id}
FIRST$^+$ (Arguments → ϵ) = {)}
FIRST$^+$ (ArgList → Type id ArgList') = {id}
FIRST$^+$ (ArgList' → , ArgList) = {,}
FIRST$^+$ (ArgList' → ϵ) = {)}

Columns for other terminals ($ are empty

Nonterminal	id	)	*	,
Function	Function → Type id (Arguments)			
Type	Type → id Type'			
Type'	Type' → ϵ		Type' → * Type'	
Arguments	Arguments → ArgList	Arguments → ϵ		
ArgList	ArgList → Type id ArgList'			
ArgList'		ArgList' → ϵ		ArgList' → , ArgList

Problem 2

$S' \to S$
$S \to LM$ — ①
$S \to Lp$ — ②
$S \to qLr$ — ③
$S \to sr$ — ④
$S \to qsp$ — ⑤
$L \to aMb$ — ⑥
$L \to s$ — ⑦
$L \to t$ — ⑧
$M \to t$ — ⑨

LR(0) Canonical collection

$I_0 = \{ S' \to \cdot S,$
$S \to \cdot LM$
$S \to \cdot Lp$
$S \to \cdot qLr$
$S \to \cdot sr$
$S \to \cdot qsp$
$L \to \cdot aMb$
$L \to \cdot s$
$L \to \cdot t$
$\}$

$I_1 = Goto(I_0, S)$
$\{ S' \to S\cdot \}$

$I_2 = Goto(I_0, L)$
$\{ S \to L\cdot M$
$S \to L\cdot p$
$M \to \cdot t$
$\}$

$I_3 = Goto(I_0, q)$
$\{ S \to q\cdot Lr$
$L \to \cdot aMb$
$L \to \cdot s$
$L \to \cdot t$
$S \to q\cdot sp$
$\}$

$I_4 = Goto(I_0, s)$
$= \{ S \to s\cdot r$
$L \to s\cdot$
$\}$

$I_5 = Goto(I_0, a)$
$\{ L \to a\cdot Mb$
$M \to \cdot t \}$

$I_6 = Goto(I_0, t)$
$\{ L \to t\cdot \}$

$I_7 = Goto(I_2, M)$
$\{ S \to LM\cdot \}$

$I_8 = Goto(I_2, p)$
$\{ S \to Lp\cdot \}$

$I_9 = Goto(I_2, t)$
$\{ M \to t\cdot \}$

$I_{10} = \text{Goto}(I_3, L)$
$\{S \to qL \cdot r\}$

$I_{11} = \text{Goto}(I_3, s)$
$\{S \to qs \cdot p$
$L \to s \cdot$
$\}$

$\text{Goto}(I_3, a) = I_5$

$\text{Goto}(I_3, t) = I_6$

$I_{12} = \text{Goto}(I_4, r) \to$
$\{S \to sr \cdot\}$

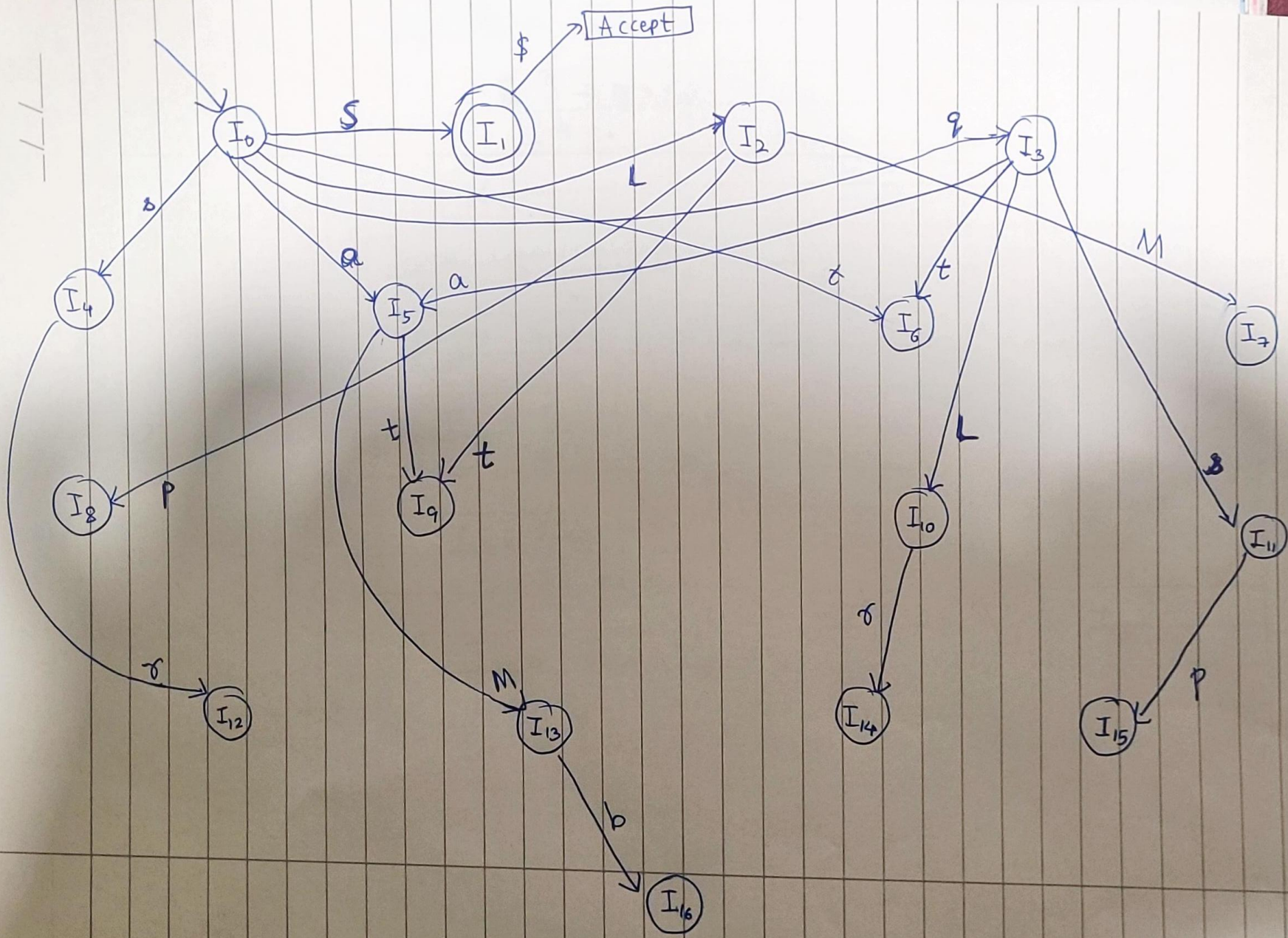
$I_{13} = \text{Goto}(I_5, M)$
$\{L \to aM \cdot b\}$

$\text{Goto}(I_5, t) = I_9$

$I_{14} = \text{Goto}(I_{10}, r)$
$\{S \to qLr \cdot\}$

$I_{15} = \text{Goto}(I_{11}, p)$
$\{S \to qsp \cdot\}$

$I_{16} = \text{Goto}(I_{13}, b)$
$\{L \to aMb \cdot\}$


Accept
$
S
L
q
M
s
a
t
r
p
b
I0
I1
I2
I3
I4
I5
I6
I7
I8
I9
I10
I11
I12
I13
I14
I15
I16

SLR parsing table

	ACTION								GOTO			
State	p	q	r	s	t	a	b	$	S	L	M	
0		s3		s4	s6	s5			1	2		
1								acc				
2	s8				s9						7	
3				s11	s6	s5				10		
4	r7		s12 r7		r7							
5					s9						13	
6	r8		r8		r8							
7								r1				
8								r2				
9							r9	r9				
10			s14									
11	s15 r7		r7		r7							
12								r4				
13							s16					
14								r3				
15								r5				
16	r6		r6		r6							

There are 2 shift reduce conflicts.
Hence the grammar is NOT SLR(1)

LR(1) collection

$I_0 = \{ S' \to \cdot S, \$$
$S \to \cdot LM, \$$
$S \to \cdot Lp, \$$
$S \to \cdot qLr, \$$
$S \to \cdot sr, \$$
$S \to \cdot qsp, \$$
$L \to \cdot aMb, t/p$
$L \to \cdot s, t/p$
$L \to \cdot t, t/p$
$\}$

$I_1 = Goto(I_0, S)$
$= \{ S' \to S\cdot, \$ \}$

$I_2 = Goto(I_0, L)$
$= \{ S \to L\cdot M, \$,$
$S \to L\cdot p, \$$
$M \to \cdot t, \$$
$\}$

$I_3 = Goto(I_0, q)$
$= \{ S \to q\cdot Lr, \$$
$S \to q\cdot sp, \$$
$L \to \cdot aMb, r$
$L \to \cdot s, r$
$L \to \cdot t, r$
$\}$

$I_4 = Goto(I_0, s)$

$= \{ S \to s \cdot r, \$$

$L \to s \cdot, t/p$

$\}$

$I_5 = Goto(I_0, a)$

$= \{ L \to a \cdot Mb, t/p$

$M \to \cdot t, b$

$\}$

$I_6 = Goto(I_0, t)$

$= \{ L \to t \cdot, t/p \}$

$I_7 = Goto(I_2, M)$

$\{ S \to LM \cdot, \$ \}$

$I_8 = Goto(I_2, p)$

$= \{ S \to Lp \cdot, \$ \}$

$I_9 = Goto(I_2, t)$

$= \{ M \to t \cdot, \$ \}$

$I_{10} = Goto(I_3, L)$

$= \{ S \to qL \cdot r, \$ \}$

$I_{11} = Goto(I_3, s)$

$= \{ S \to qs \cdot p, \$$

$L \to s \cdot, r$

$\}$

$I_{12} = Goto(I_3, a)$

$= \{ L \to a \cdot Mb, r$

$M \to \cdot t, b$

$\}$

$I_{13} = Goto(I_3, t) = \{ L \to t\bullet, r \}$

$I_{14} = Goto(I_4, r) = \{ S \to sr\bullet, \$ \}$

$I_{15} = Goto(I_5, M) = \{ L \to aM\bullet b, t/\beta \}$

$I_{16} = Goto(I_5, t) = \{ M \to t\bullet, b \}$

$I_{17} = Goto(I_{10}, r) = \{ S \to qLr\bullet, \$ \}$

$I_{18} = Goto(I_{11}, p) = \{ S \to qsp\bullet, \$ \}$

$I_{19} = Goto(I_{12}, M) = \{ L \to aM\bullet b, r \}$

$Goto(I_{12}, t) = I_{16}$

$I_{20} = Goto(I_{15}, b) = \{ L \to aMb\bullet, t/\beta \}$

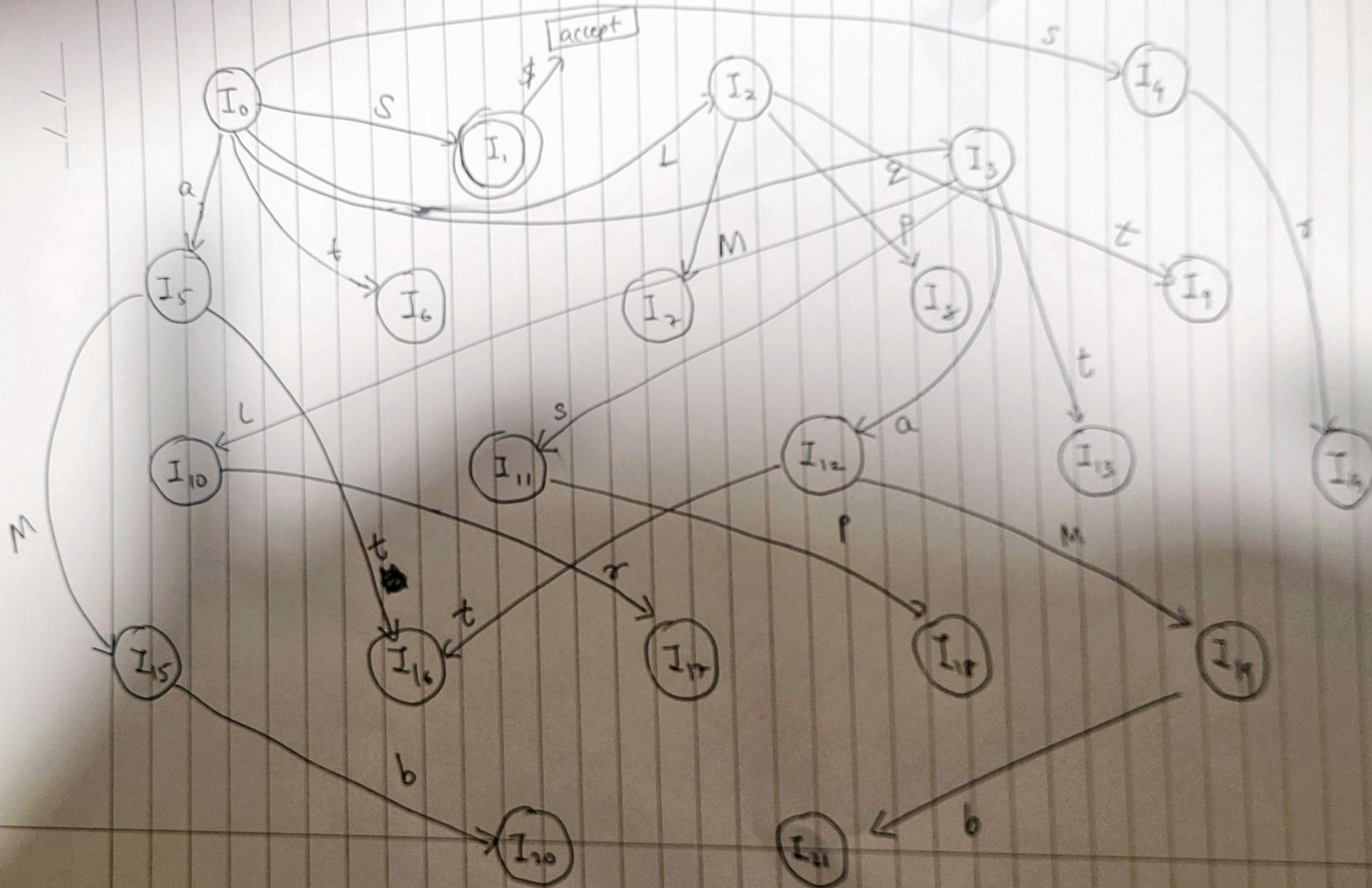
$I_{21} = Goto(I_{19}, b) = \{ L \to aMb\bullet, r \}$

Matching cores

1) I_5, I_{12}
2) I_6, I_{13}
3) I_9, I_{18}
4) I_{15}, I_{19}
5) I_{20}, I_{21}

FIRST (S') = {a, s, a, t}
FIRST (S) = {q, s, a, t}
FIRST (L) = {a, s, t}
FIRST (M) = {t}

FOLLOW (S') = {$}
FOLLOW (S) = {$}
FOLLOW (L) = ~~{b, $, p, r}~~ {p, r, t}
FOLLOW (M) = {b, $}



accept
$
S
s
L
q
M
p
t
a
r
b
I_0
I_1
I_2
I_3
I_4
I_5
I_6
I_7
I_8
I_9
I_{10}
I_{11}
I_{12}
I_{13}
I_{14}
I_{15}
I_{16}
I_{17}
I_{18}
I_{19}
I_{20}
I_{21}

LALR collection

$I_0 = \{ S' \to \cdot S, \$$
$S \to \cdot LM, \$$
$S \to \cdot Lp, \$$
$S \to \cdot qLr, \$$
$S \to \cdot sr, \$$
$S \to \cdot qsp, \$$
$L \to \cdot aMb, t/p$
$L \to \cdot s, t/p$
$L \to \cdot t, t/p$
$\}$

$I_1 = \text{Goto}(I_0, S) = \{ S' \to S\cdot, \$ \}$

$I_2 = \text{Goto}(I_0, L) = \{ S \to L\cdot M, \$$
$S \to L\cdot p, \$$
$M \to \cdot t, \$ \}$

$I_3 = \text{Goto}(I_0, q) = \{ S \to q\cdot Lr, \$$
$S \to q\cdot sp, \$$
$L \to \cdot aMb, r$
$L \to \cdot s, r$
$L \to \cdot t, r \}$

$I_4 = \text{Goto}(I_0, s) = \{ S \to s\cdot r, \$$
$L \to s\cdot, t/p \}$

$I_{5,12} = \{ L \to a\cdot Mb, t/p/r$
$M \to \cdot t, b \}$

$I_{6,13} = \{ L \to t\cdot, t/p/r \}$

$I_7 = \{ S \to LM\cdot, \$ \}$

$I_8 = \{ S \to Lp\cdot, \$ \}$

$I_{9,16} = \{ M \to t\cdot, \$/b \}$

$I_{10} = \{ S \to qL\cdot r, \$ \}$

$I_{11} = \{ S \to qs\cdot p, \$$
$L \to s\cdot, r \}$

$I_{14} = \{ S \to sr\cdot, \$ \}$

$I_{15,19} = \{ L \to aM\cdot b, t/p/r \}$

$I_{17} = \{ S \to qLr\cdot, \$ \}$

$I_{18} = \{ S \to qsp\cdot, \$ \}$

$I_{20,21} = \{ L \to aMb\cdot, t/p/r \}$

LALR parsing table

	ACTION								GOTO		
	p	q	r	s	t	a	b	$	S	L	M
0		S3		S4	S6,13	S5,12			1	2	
1								acc			
2	S8				S9,16						7
3				S11	S6,13	S5,12				10	
4	r7		S14		r7						
5,12					S16,9						15,19
6,13	r8		r8		r8						
7								r1			
8								r2			
9,16							r9	r9			
10			S17								
11	S18		r7								
14								r4			
15,19							S20,21				
17								r3			
18								r5			
20,21	r6		r6		r6						

Problem 3:

Instructions to run the code

1. Paste the input text in the file **`input.txt`**
2. Go to directory problem3 and execute the following command
   `./run.sh`