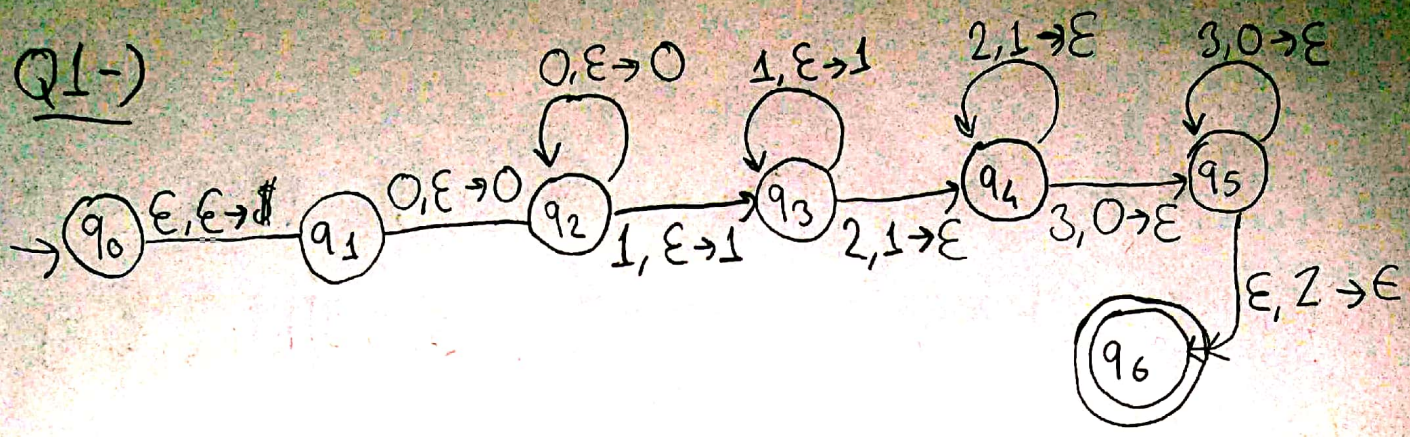
Q1-)



$\{0^m 1^n 2^n 3^m \mid n \geq 1, m \geq 1\}$

S → 0E3

E → 1P2 | 0E3

P → 1P2 | ε

$\delta(q_0, \epsilon, \epsilon) \to (q_1, \epsilon)$
$\delta(q_1, 0, \epsilon) \to (q_2, 0)$
$\delta(q_2, 0, \epsilon) \to (q_2, 0)$
$\delta(q_2, 1, \epsilon) \to (q_3, 1)$
$\delta(q_3, 1, \epsilon) \to (q_3, 1)$
$\delta(q_3, 2, 1) \to (q_4, \epsilon)$
$\delta(q_4, 2, 1) \to (q_4, \epsilon)$
$\delta(q_4, 3, 0) \to (q_5, \epsilon)$
$\delta(q_5, 3, 0) \to (q_5, \epsilon)$
$\delta(q_5, \epsilon, z) \to (q_6, \epsilon)$

0123

$\delta(q_0, \epsilon, z) \vdash \delta(q_1, 0123, z) \vdash \delta(q_2, 123, 0z) \vdash \delta(q_3, 23, 10z) \vdash \delta(q_4, 3, 0z)$

$\vdash \delta(q_5, \epsilon, z) \vdash (q_6, \epsilon, \epsilon)$

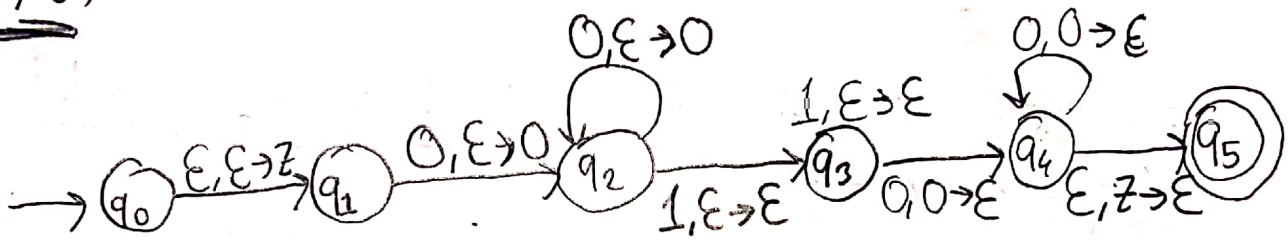
001233

$\delta(q_0, \epsilon, Z) \vdash (q_1, 001233, Z) \vdash \delta(q_1, 01233, 0Z) \vdash \delta(q_2, 1233, 00Z) \vdash$

$\delta(q_3, 233, 100Z) \vdash \delta(q_4, 33, 00Z) \vdash \delta(q_5, 3, 0Z) \vdash \delta(q_5, \epsilon, Z)$

$\vdash \delta(q_6, \epsilon, \epsilon)$

Q2-)



$\delta(q_0, \epsilon, \epsilon) \to (q_1, \epsilon)$

$\delta(q_1, 0, \epsilon) \to (q_2, 0)$

$\delta(q_2, 0, \epsilon) \to (q_2, 0)$

$\delta(q_2, 1, \epsilon) \to (q_3, \epsilon)$

$\delta(q_3, 1, \epsilon) \to (q_3, \epsilon)$

$\delta(q_3, 0, 0) \to (q_4, \epsilon)$

$\delta(q_4, \epsilon, z) \to (q_5, \epsilon)$

$\delta(q_4, 0, 0) \to (q_4, \epsilon)$

00011000

$\delta(q_0, \epsilon, z) \vdash \delta(q_1, 00011000, z) \vdash$

$\delta(q_2, 0011000, 0z) \vdash \delta(q_2, 011000, 00z) \vdash$

$\delta(q_2, 11000, 000z) \vdash \delta(q_3, 1000, 00z) \vdash$

$\delta(q_3, 000, 000z) \vdash \delta(q_4, 00, 00z) \vdash$

$\delta(q_4, 0, 0z) \vdash \delta(q_5, \epsilon, z) \vdash (q_5, \epsilon, \epsilon)$

Q3-)

(-)

Step 1

$SO \to S$

$S \to ASA \mid ab$

$A \to B \mid S$

$B \to b \mid \epsilon$

Step 2

Eliminate null production

$SO \to S$

$S \to ASA \mid aB \mid a$

$A \to B \mid S \mid \epsilon$

$B \to b$

$SO \to S$

$S \to ASA \mid aB \mid a \mid AS \mid SA \mid S$

$A \to B \mid S$

$B \to b$

Eliminate unit pyruduction

$SO \to ASA \mid aB \mid a \mid AS \mid SA$

$S \to ASA \mid aB \mid a \mid AS \mid SA$

$A \to b \mid ASA \mid aB \mid a \mid AS \mid SA$

$B \to b$

Step 3-4

$X \to a$

$Y \to AS$

$SO \to YA \mid XB \mid a \mid AS \mid SA$

$S \to YA \mid XB \mid a \mid AS \mid SA$

$A \to b \mid YA \mid XB \mid a \mid AS \mid SA$

$B \to b$

2-) Step 1

$S0 \to S$

$S \to AbA$

$A \to Aa \mid \varepsilon$

Step 2

Eliminate null prod.

$S0 \to S$

$S \to AbA \mid bA \mid Ab \mid b$

$A \to Aa \mid a$

Eliminate unit prod.

$S0 \to AbA \mid bA \mid Ab \mid b$

$S \to AbA \mid bA \mid Ab \mid b$

$A \to Aa \mid a$

Step 3

$X \to b \quad Y \to AX$

$S0 \to AXA \mid XA \mid AX \mid b$

$S \to AXA \mid XA \mid AX \mid b$

$A \to AY \mid a$

Step 4