

Q1. Construct NPDAs that accept the following regular languages

$$(a) L_1 = L(aaa^*bbb)$$

$$\delta(q_0, a, z) = (q_0, a^*z)$$

$$\delta(q_0, a, a) = (q_0, aa)$$

$$\delta(q_0, b, a) = (q_1, b^*a)$$

$$\delta(q_0, b, z) = (q_1, bz)$$

$$\delta(q_0, \lambda, z) = (q_1, z)$$

$$\delta(q_1, b, z) = (q_1, bz)$$

$$\delta(q_1, a, a) = (q_1, aa)$$

$$\delta(q_1, \lambda, a) = (q_2, b)$$

$$\delta(q_2, b, b) = (q_2, bb)$$

$$\delta(q_2, a, b) = (q_3, ab)$$

$$\delta(q_2, b, z) = (q_3, bz)$$

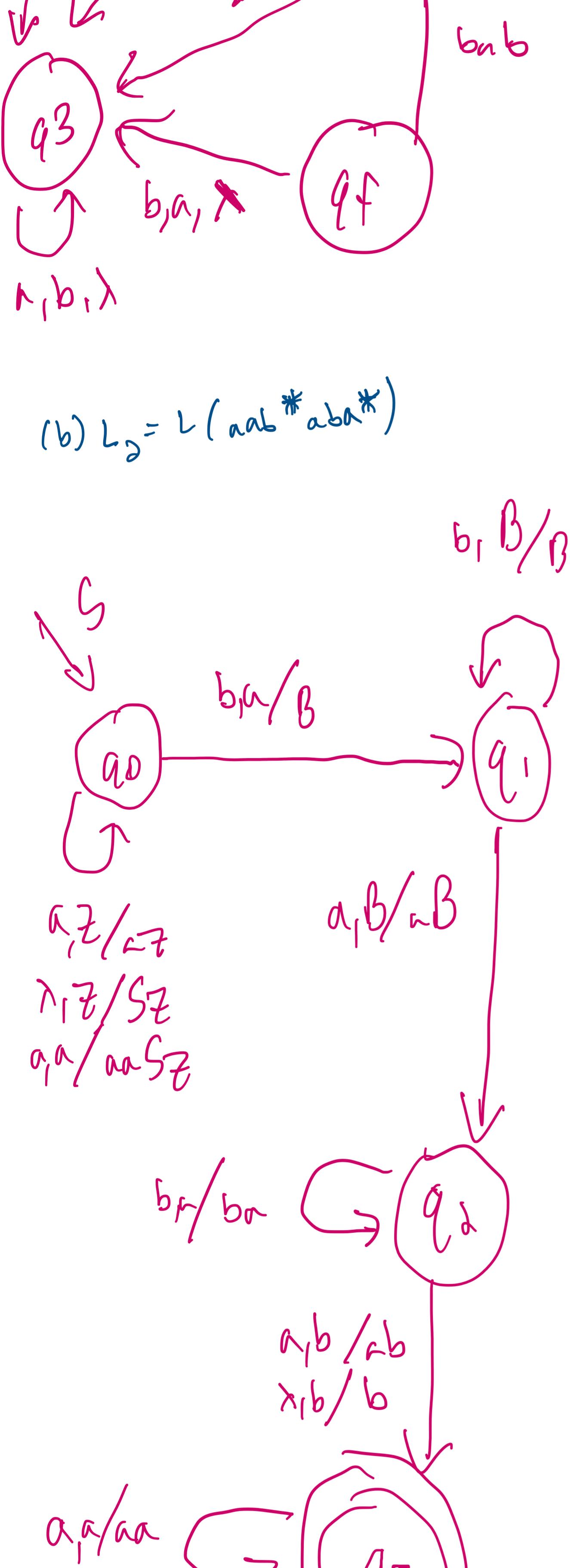
$$\delta(q_3, a, b) = (q_f, ab)$$

$$\delta(q_3, b, a) = (q_f, ba)$$

$$\delta(q_3, \lambda, a) = (q_f, a)$$

$$\delta(q_3, a, \lambda) = (q_f, a)$$

$$\delta(q_3, \lambda, \lambda) = (q_f, \lambda)$$



$$S \rightarrow aaaa^*B \mid \lambda$$

$$B \rightarrow bbb$$

$$\delta(q_0, x, z) = (q_0, Sz)$$

$$\delta(q_0, a, z) = (q_0, az)$$

$$\delta(q_0, a, a) = (q_1, aa)$$

$$\delta(q_1, a, a) = (q_1, aaa)$$

$$\delta(q_1, \lambda, a) = (q_2, b)$$

$$\delta(q_2, b, b) = (q_2, bb)$$

$$\delta(q_2, a, b) = (q_3, ab)$$

$$\delta(q_2, b, z) = (q_3, bz)$$

$$\delta(q_3, a, b) = (q_3, bz)$$

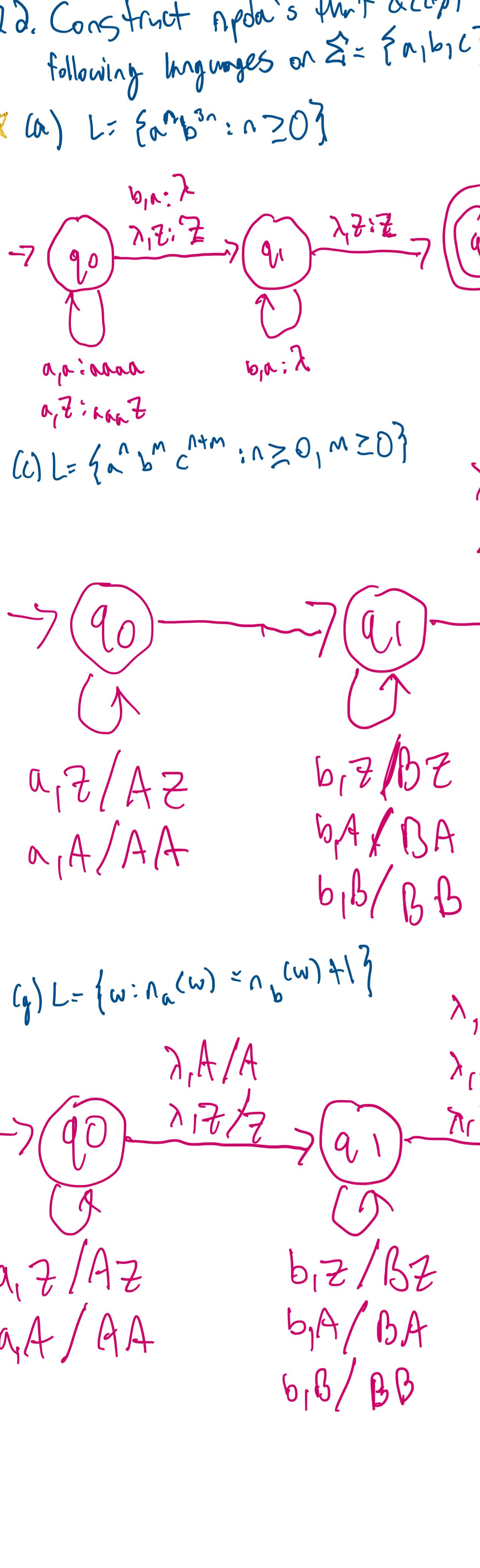
$$\delta(q_3, b, a) = (q_f, ab)$$

$$\delta(q_3, a, \lambda) = (q_f, a)$$

$$\delta(q_3, \lambda, a) = (q_f, a)$$

$$\delta(q_3, a, \lambda) = (q_f, \lambda)$$

$$(b) L_2 = L(aab^*abb^*)$$



$$S \rightarrow aabBabbA$$

$$B \rightarrow b \mid \lambda$$

$$A \rightarrow a \mid \lambda$$

$$\delta(q_0, a, z) = (q_0, az)$$

$$\delta(q_0, \lambda, z) = (q_0, Sz)$$

$$\delta(q_0, a, a) = (q_0, aaa)$$

$$\delta(q_0, b, a) = (q_1, Ba)$$

$$\delta(q_1, b, B) = (q_1, BBaa)$$

$$\delta(q_1, a, b) = (q_2, ab)$$

$$\delta(q_2, b, A) = (q_2, Ba)$$

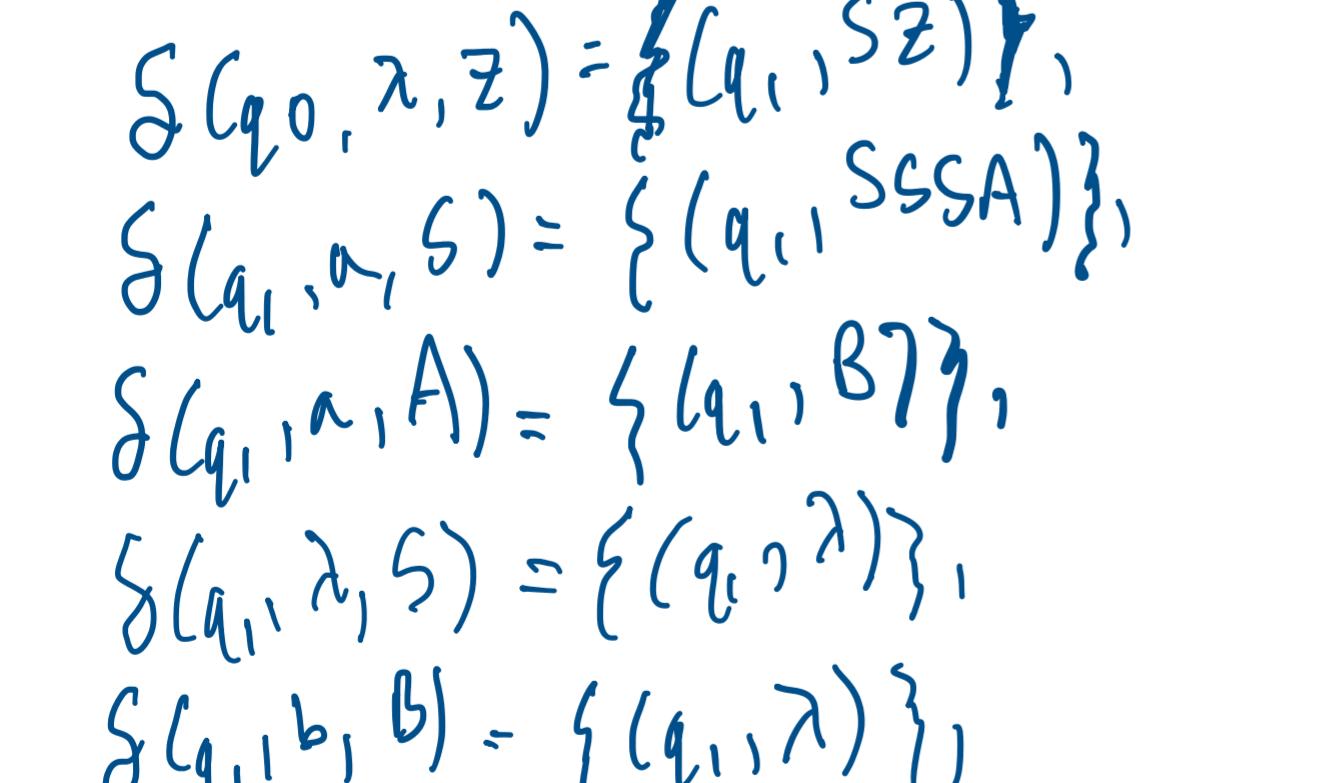
$$\delta(q_2, a, b) = (q_3, ab)$$

$$\delta(q_3, a, a) = (q_3, aa)$$

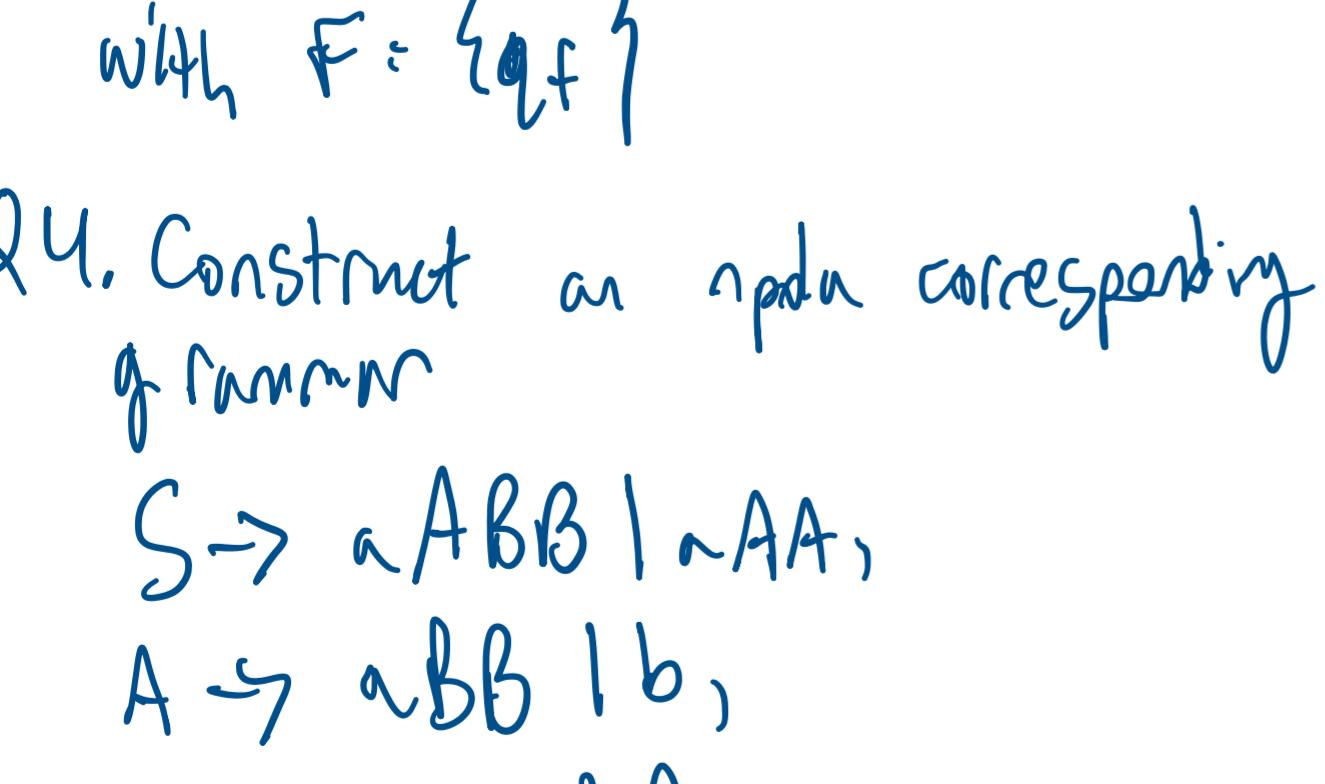
$$\delta(q_3, \lambda, b) = (q_3, b)$$

Q2. Construct NPDAs that accept the following languages on $\Sigma = \{a, b, c\}$

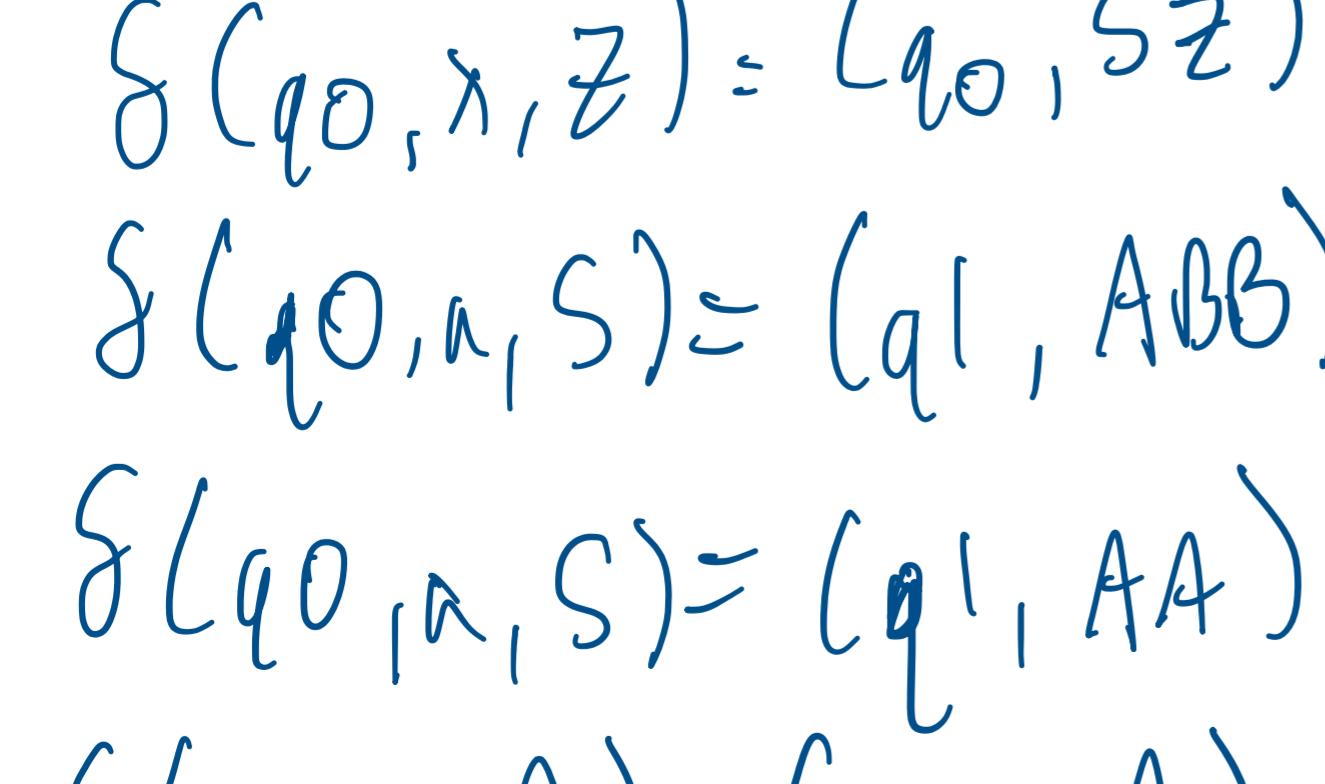
$$★ (a) L = \{a^n b^{3n} : n \geq 0\}$$



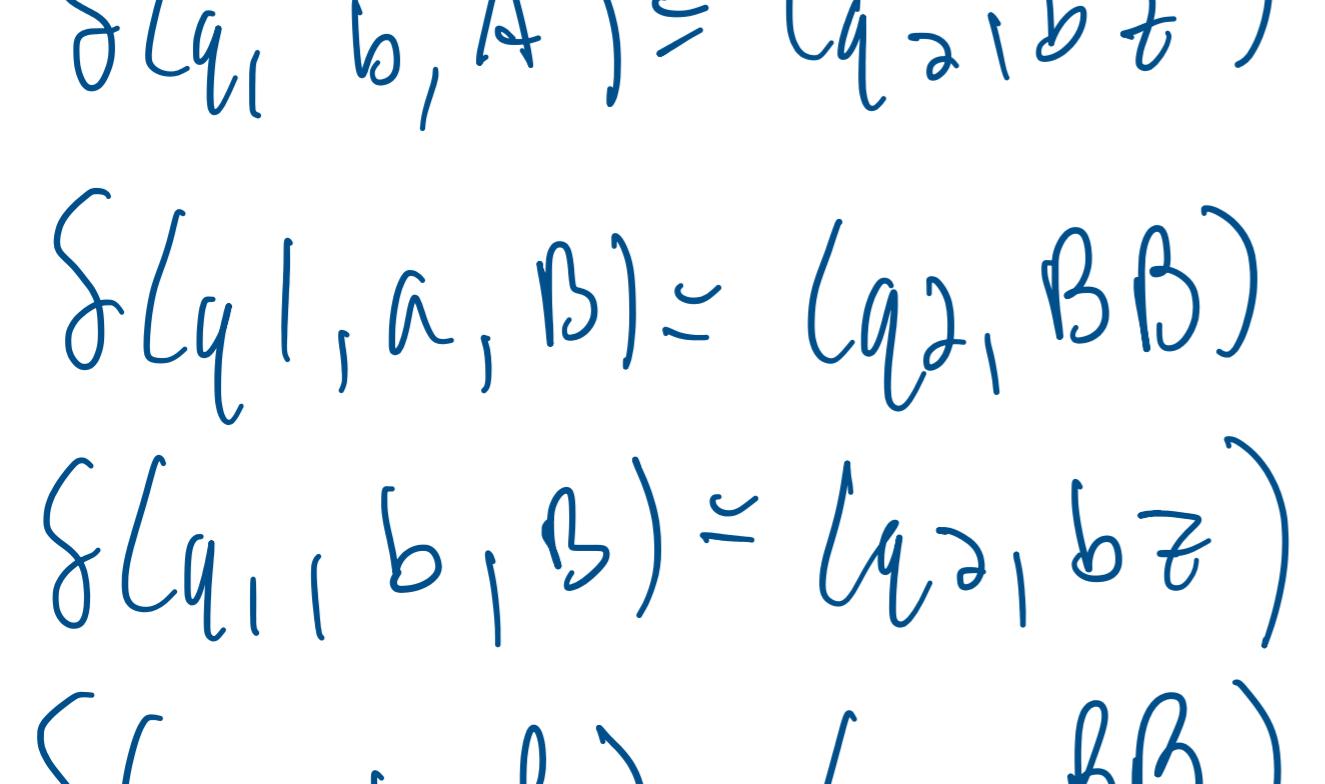
$$(c) L = \{a^n b^m c^{n+m} : n \geq 0, m \geq 0\}$$



$$(d) L = \{w : n_a(w) = n_b(w) + 1\}$$



$$(e) L = \{w : n_a(w) = n_b(w) + 1\}$$



$$(f) L = \{w : n_a(w) = n_b(w) + 1\}$$

$$\text{with } F = \{q_f\}$$

Q3. Construct an NPA corresponding to the grammar

$$S \rightarrow aSSSnb \mid \lambda$$

$$S \rightarrow aSSSA \mid \lambda$$

$$A \rightarrow nb,$$

$$B \rightarrow b$$

$$\delta(q_0, a, z) = \{(q_1, Sz)\},$$

$$\delta(q_1, a, S) = \{(q_1, SSSA)\},$$

$$\delta(q_1, a, A) = \{(q_1, BA)\},$$

$$\delta(q_1, a, S) = \{(q_1, \lambda)\},$$

$$\delta(q_1, b, B) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, B) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, B) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, A) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, A) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, S) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, S) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, a) = \{(q_1, \lambda)\},$$

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$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, a) = \{(q_1, \lambda)\},$$

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$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

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$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

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$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, \lambda) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, \lambda, a) = \{(q_1, \lambda)\},$$

$$\delta(q_1, a, \lambda) = \{(q_1, \lambda)\},$$

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