

Q1. Construct NPDAs that accept the following regular languages

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

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

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

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

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

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

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

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

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

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

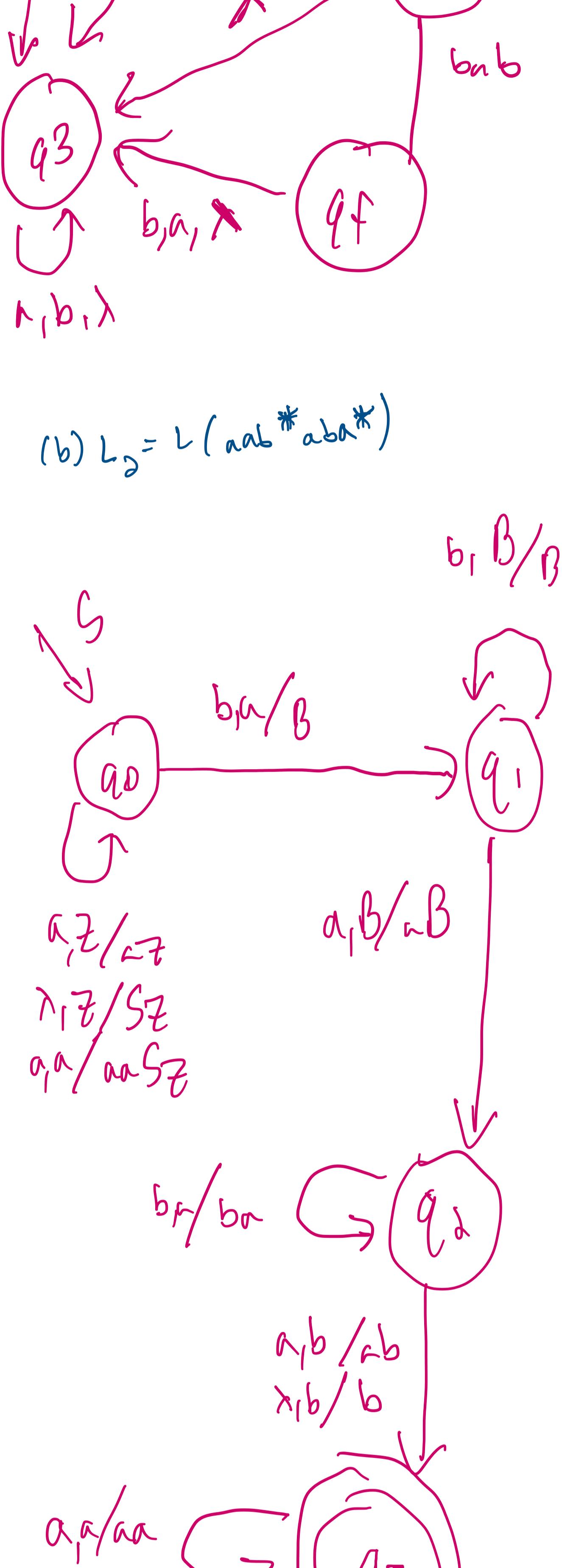
$$\delta(q_2, a, b) = (q_3, ab)$$

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

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

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

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



$$S \rightarrow aaaa^*b | \lambda$$

$$B \rightarrow bbb$$

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

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

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

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

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

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

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

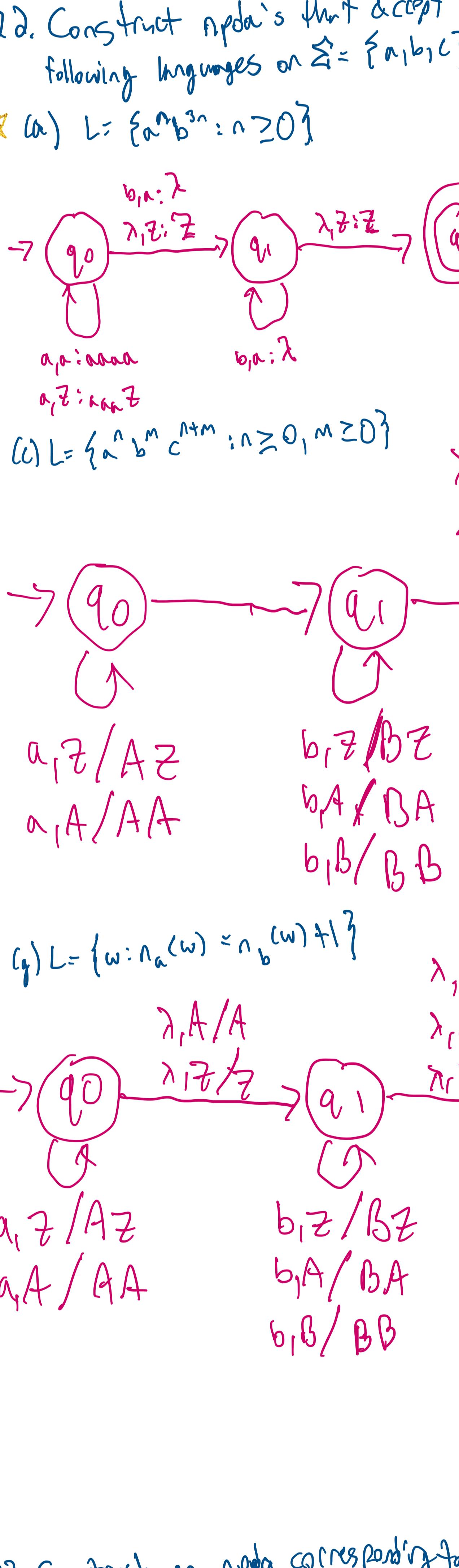
$$\delta(q_2, b, z) = (q_3, bz)$$

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

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

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

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



$$S \rightarrow aab B abb A$$

$$B \rightarrow b | \lambda$$

$$A \rightarrow a | \lambda$$

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

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

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

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

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

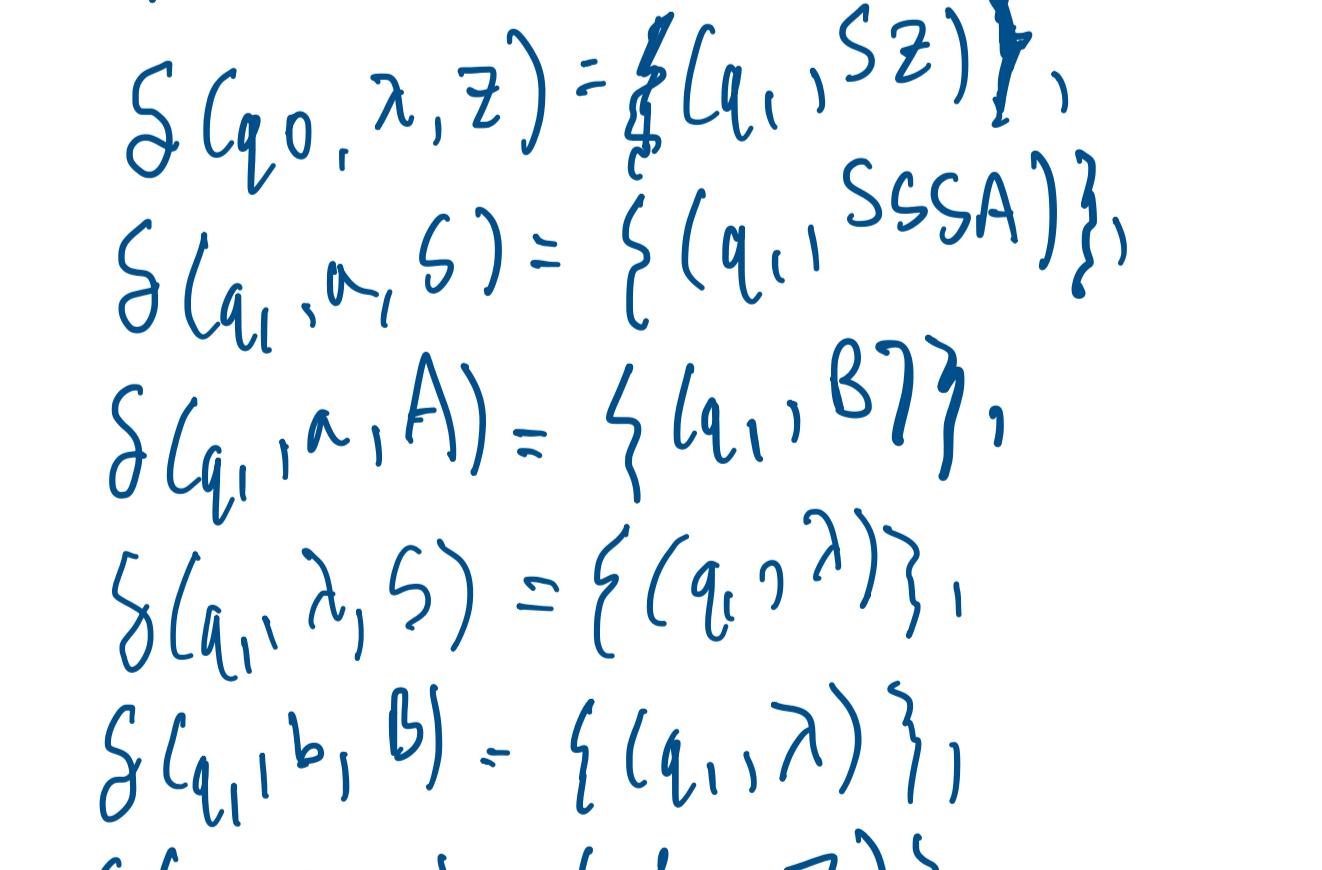
$$\delta(q_1, a, b) = (q_2, ab)$$

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

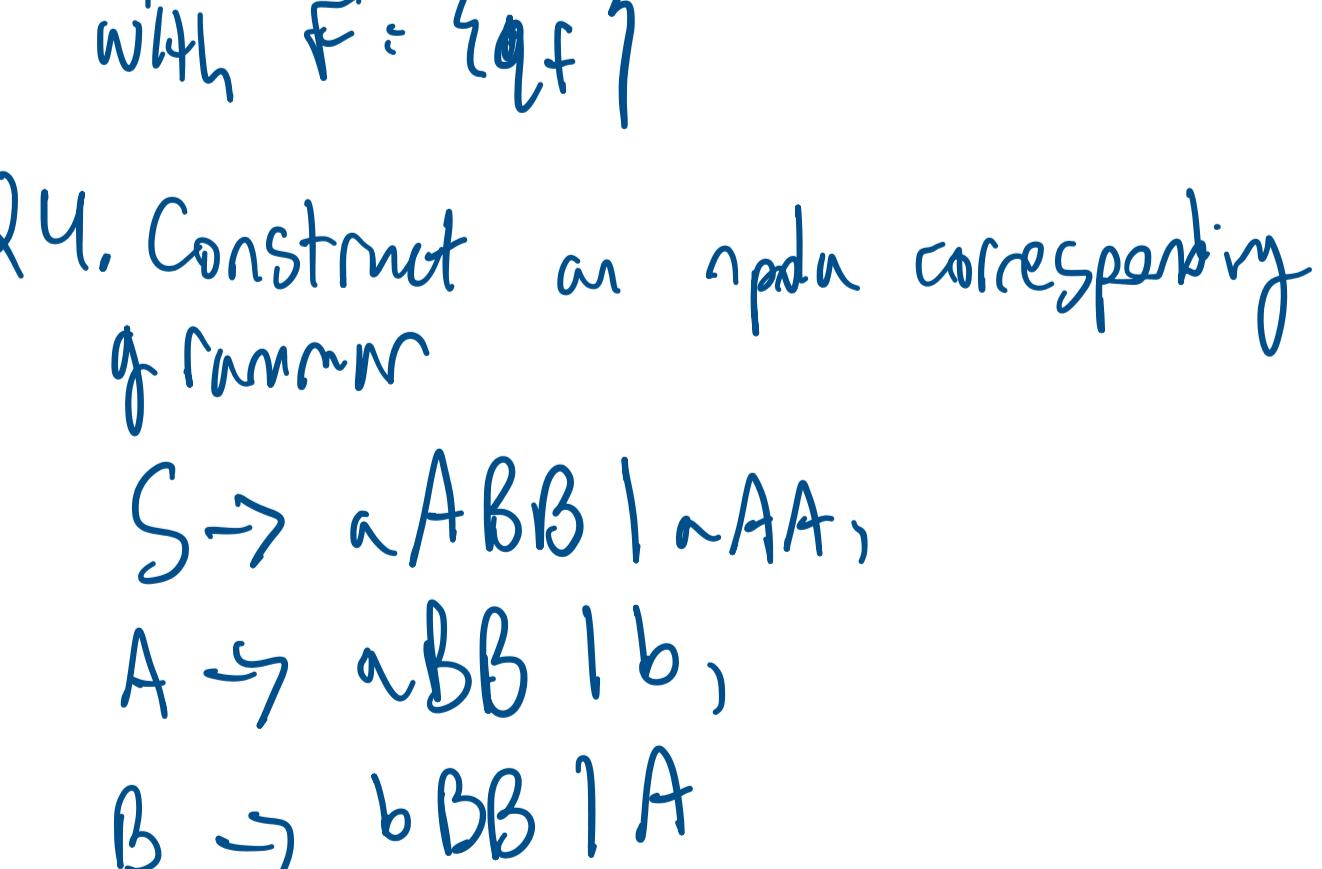
$$\delta(q_3, a, b) = (q_3, b)$$

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

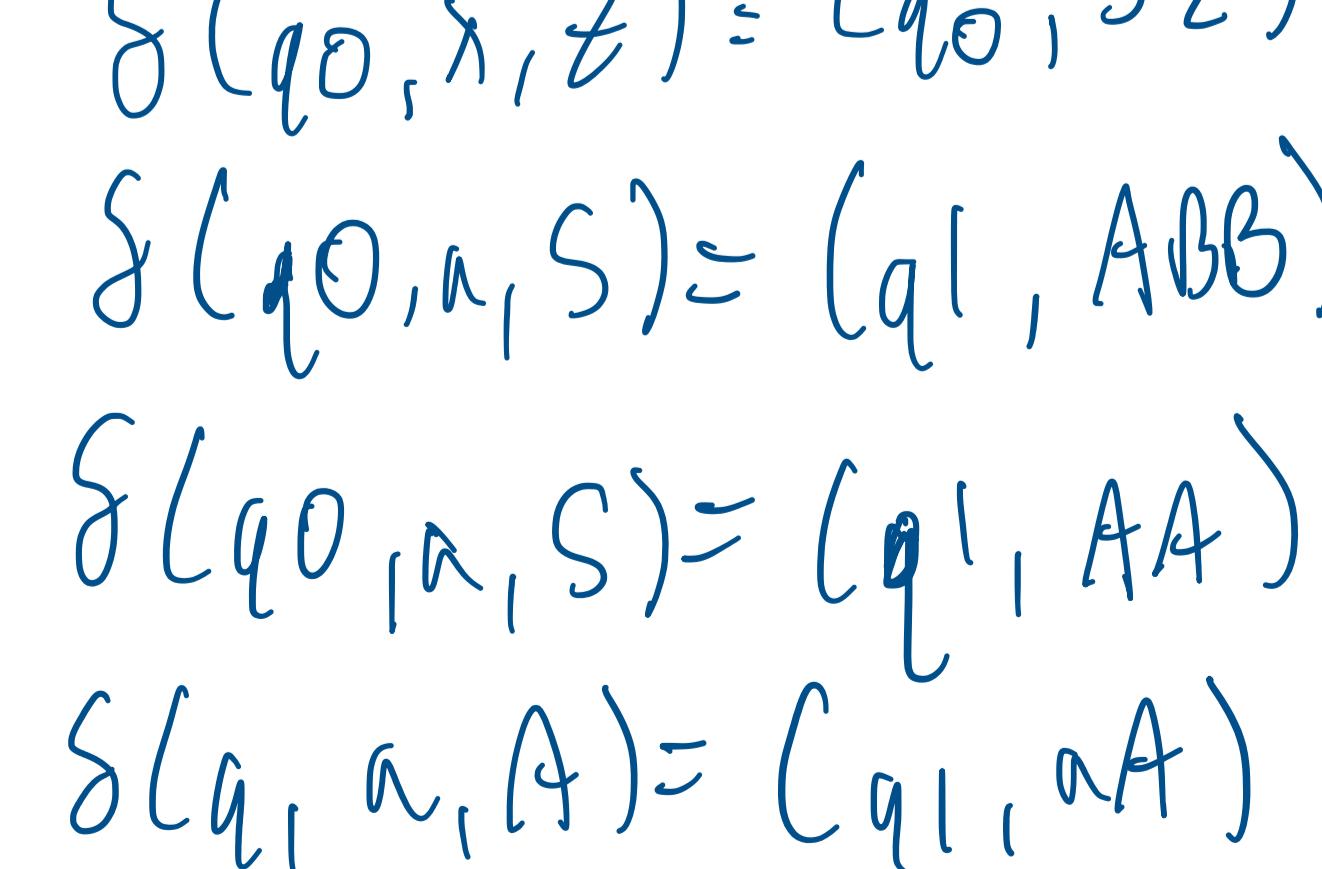
$$★ (a) L = \{a^n b^{3n} : n \geq 0\}$$



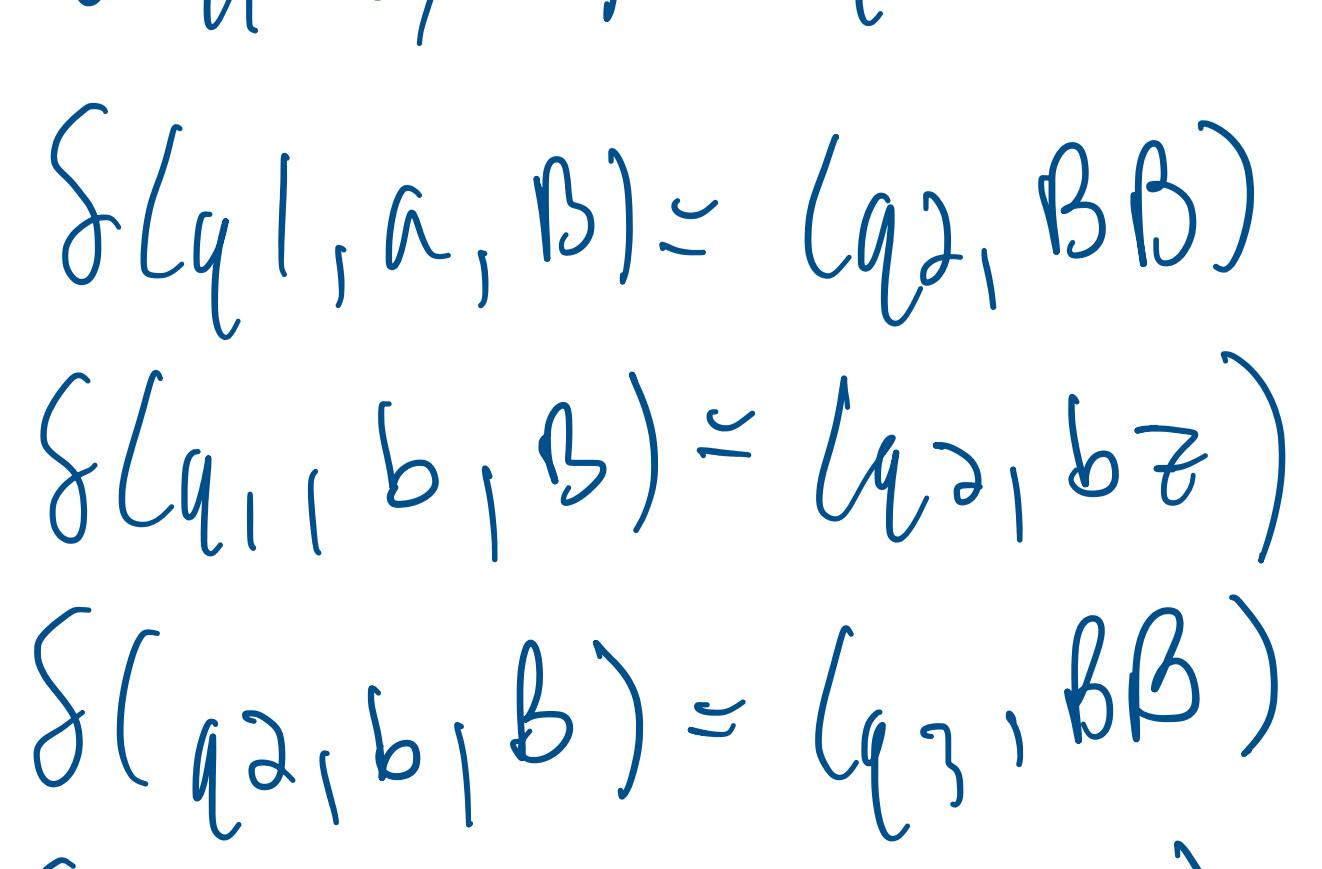
$$(c) L = \{a^n b^m c^{n+m} : n \geq 0, m \geq 0\}$$



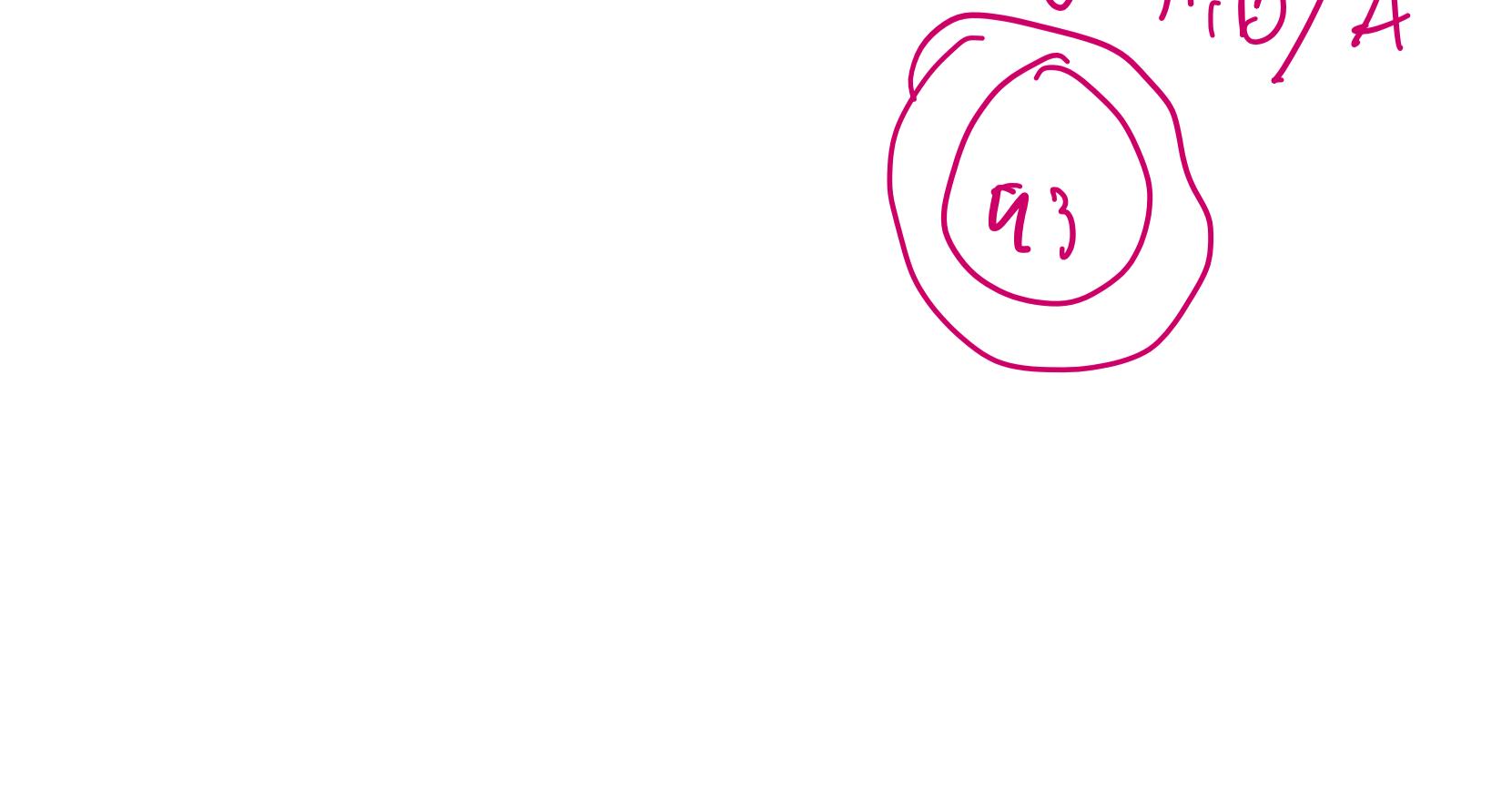
$$(d) L = \{w : n_a(w) = n_b(w) + 1\}$$



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



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



$$Q4. Construct an NPA corresponding to the grammar$$

$$S \rightarrow aABB | aAA,$$

$$A \rightarrow abb | b,$$

$$B \rightarrow bBB | A$$

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

$$\delta(q_0, a, S) = (q_1, ABB)$$

$$\delta(q_0, a, A) = (q_1, AA)$$

$$\delta(q_1, a, A) = (q_1, AA)$$

$$\delta(q_1, b, A) = (q_2, Bz)$$

$$\delta(q_1, a, B) = (q_2, BB)$$

$$\delta(q_1, b, B) = (q_3, BB)$$

$$\delta(q_2, a, B) = (q_3, A)$$



$$S \rightarrow aSSSnb | \lambda$$

$$S \rightarrow aSSSA | \lambda$$

$$A \rightarrow nb,$$

$$B \rightarrow b$$

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

$$\delta(q_0, a, S) = (q_1, ABB)$$

$$\delta(q_0, a, A) = (q_1, AA)$$

$$\delta(q_1, a, A) = (q_1, AA)$$

$$\delta(q_1, b, A) = (q_2, Bz)$$

$$\delta(q_1, b, B) = (q_3, BB)$$

$$\delta(q_2, a, B) = (q_3, A)$$



$$S \rightarrow aSSSnb | \lambda$$

$$S \rightarrow aSSSA | \lambda$$

$$A \rightarrow nb,$$

$$B \rightarrow b$$

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

$$\delta(q_0, a, S) = (q_1, ABB)$$

$$\delta(q_0, a, A) = (q_1, AA)$$

$$\delta(q_1, a, A) = (q_1, AA)$$

$$\delta(q_1, b, A) = (q_2, Bz)$$

$$\delta(q_1, b, B) = (q_3, BB)$$

$$\delta(q_2, a, B) = (q_3, A)$$



$$S \rightarrow aSSSnb | \lambda$$

$$S \rightarrow aSSSA | \lambda$$

$$A \rightarrow nb,$$

$$B \rightarrow b$$

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

$$\delta(q_0, a, S) = (q_1, ABB)$$

$$\delta(q_0, a, A) = (q_1, AA)$$

$$\delta(q_1, a, A) = (q_1, AA)$$

$$\delta(q_1, b, A) = (q_2, Bz)$$

$$\delta(q_1, b, B) = (q_3, BB)$$

$$\delta(q_2, a, B) = (q_3, A)$$

