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Problem 1

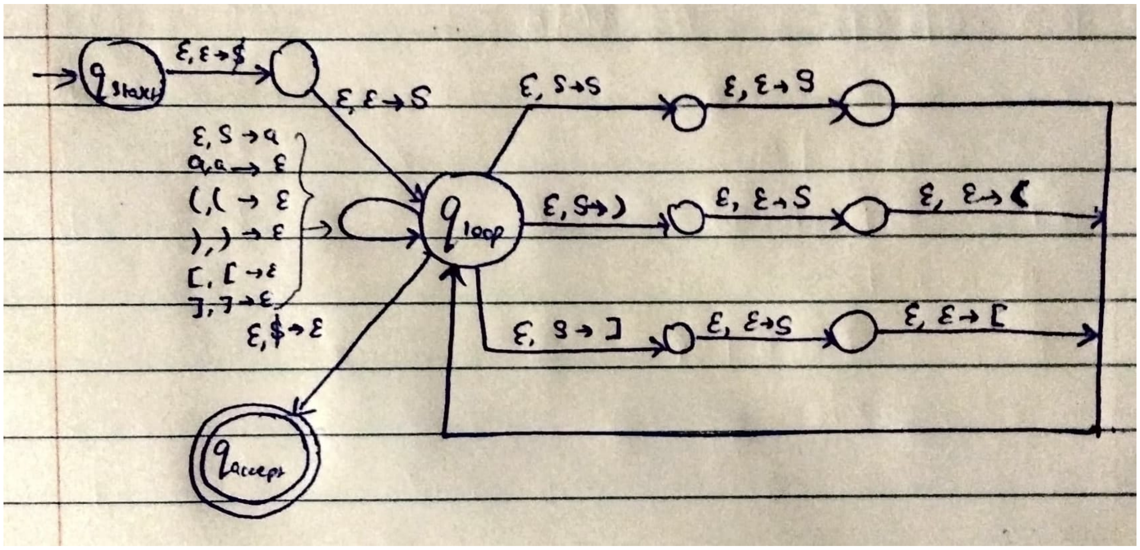
The language consisting of strings of the form $a^i b^j$ where $i \neq j$ requires the grammar to capture the imbalance between the number of a's and b's.

We will re-write $i \neq j$ as $i < j$ or $i > j$.

L = $\{a^i b^j \text{ ; } i < j \text{ or } i > j\}$

S $\rightarrow A_{i<j} \mid A_{i>j}$
$A_{i<j} \rightarrow$ a$A_{i<j}$b | bB
B $\rightarrow$ bB | ε
$A_{i>j} \rightarrow$ a$A_{i>j}$b | aX
X $\rightarrow$ aX | ε

Problem 2


q start
ε, ε → $
ε, ε → S
ε, S → S
ε, ε → S
ε, S → a
a, a → ε
(, (→ ε
),) → ε
[, [→ ε
],] → ε
ε, $ → ε
q loop
ε, S →)
ε, ε → S
ε, ε → (
ε, S →]
ε, ε → S
ε, ε → [
q accept

Problem 3

A context free grammar (CFG) is in Chomsky Normal Form (CNF) if all production rules satisfy one of the following conditions:

- A non-terminal generating a terminal (e.g.; X → x)
- A non-terminal generating two non-terminals (e.g.; X → YZ)
- Start symbol generating ε. (e.g.; S → ε)

Step 1: As start symbol S appears on the RHS, we will create a new production rule S0 → S. Therefore, the grammar will become:

S0 → S
S → aSb | c | SS

Step 2: The grammar does not contain any null production.

Step 3: The rule S → aSb violates CNF because it has a unit production (a single terminal "a") on the right-hand side and rewrites to a non-terminal (S) followed by two symbols (a terminal "b"). After eliminating unit productions:

S0 → aSb | c | SS
S → aSb | c | SS

Step 4: In production rule S0 → aSb and S → aSb, RHS has more than two symbols, removing it from grammar yields:

S0 → XB | c | SS
S → XB | c | SS
X → aS
B → b

Step 5: After eliminating terminals from RHS since they exist with other terminals or non-terminals yields:

S0 → XB | c | SS
S → XB | c | SS
X → AS
A → a
B → b

Problem 4

Context-free grammar: S → SS | aSb | bSa | ε