Problem 1

Give prefix and postfix notations for the following infix expressions using the precedence and associativity of operations as discussed in lecture 4, p. 16.

\[(a*2/5) - (a^3\times5+d/e+3) - (a+b+c)\]

Problem 2

For each of the following strings, draw a parse tree with respect to the grammar for arithmetic expressions as shown in Fig. 2.6 in Sethi, p. 42. In addition, draw the abstract syntax tree.

2.1 1-3*5
2.2 (1*3)-5
2.3 ((1))/(3+(5))

Problem 3

Assume you have a language with the binary operators $\$, @ and %. Expressions in this language may contain one letter variables (lower case) and single digit constants.

3.1 Give a context-free grammar in BNF that implements the following:

- **Associativity:**
  - $\$: Left to Right (left associative)
  - %: Right to Left (right associative)

- **Precedence:**
  - $\$: weak
  - %: stronger
  - @: strongest

3.2 Give the parse tree and abstract syntax tree generated by your grammar for the expression:

\[a@b@1%3@5%a@d\]
Problem 4
What language is generated by the following grammars? In each case BRIEFLY justify your answer.

4.1  \[ S ::= S S + | S S^* | \epsilon \]
4.2  \[ S ::= aSb | a \]
4.3  \[ S ::= 0S1S | 1S0S | \epsilon \]

Which of these grammars are ambiguous? If the grammar is ambiguous, give two parse trees for the same sentence. If the grammar is not ambiguous, BRIEFLY explain why each sentence has a unique parse tree.

Problem 5
\[ S ::= aSb | aSbb | \epsilon \]

Prove that all sentences generated by the grammar have the following properties:

- all occurrences of symbol “b” follow all occurrences of symbol “a”

- There are at least as many occurrences of symbol “b” as of symbol “a”.

Hint: use induction