## Q1: Parse Tree and Leftmost Derivation for Four Statements

The BNF grammar :

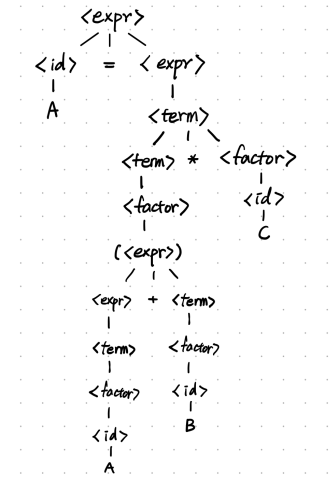
```
<assign> → <id> = <expr>
<id> → A | B | C
<expr> → <expr> + <term> | <term>
<term> → <term> * <factor> | <factor>
<factor> → ( <expr> ) | <id>
```

**1.** `A = ( A + B ) * C`

**Leftmost derivation**:

```
<assign>
<id> = <expr>
A = <expr>
A = <term>
A = <term> * <factor>
A = <factor> * <factor>
A = ( <expr> ) * <factor>
A = ( <expr> + <term> ) * <factor>
A = ( <term> + <term> ) * <factor>
A = ( <factor> + <term> ) * <factor>
A = ( <id> + <term> ) * <factor>
A = ( A + <term> ) * <factor>
A = ( A + <factor> ) * <factor>
A = ( A + <id> ) * <factor>
A = ( A + B ) * <factor>
A = ( A + B ) * <id>
A = ( A + B ) * C
```

**Parse tree**:

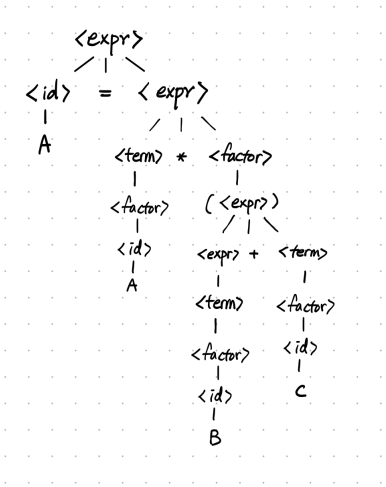



**2.** `A = B + C + A`

**Leftmost derivation**:

```
<assign>
<id> = <expr>
A = <expr>
A = <expr> + <term>
A = <expr> + <term> + <term>
A = <term> + <term> + <term>
A = <factor> + <term> + <term>
A = <id> + <term> + <term>
A = B + <term> + <term>
A = B + <factor> + <term>
A = B + <id> + <term>
A = B + C + <term>
A = B + C + <factor>
A = B + C + <id>
A = B + C + A
```

**Parse tree**:

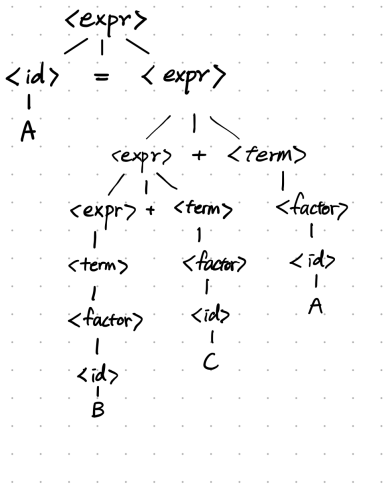



**3.** `A = A * (B + C)`

**Leftmost derivation**:

```
<assign>
<id> = <expr>
A = <expr>
A = <term>
A = <term> * <factor>
A = <factor> * <factor>
A = <id> * <factor>
A = A * <factor>
A = A * ( <expr> )
A = A * ( <expr> + <term> )
A = A * ( <term> + <term> )
A = A * ( <factor> + <term> )
A = A * ( <id> + <term> )
A = A * ( B + <term> )
A = A * ( B + <factor> )
A = A * ( B + <id> )
A = A * ( B + C )
```

**Parse tree**:

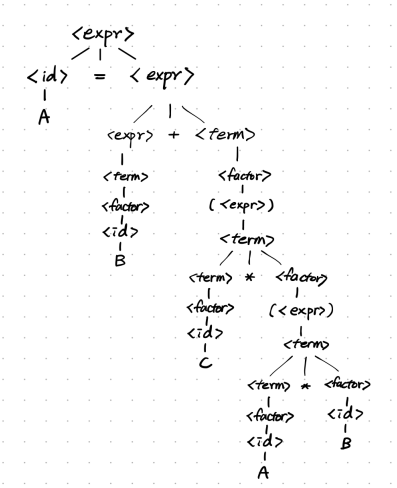



**4.** `A = B + (C * (A * B))`

**Leftmost derivation**:

```
<assign>
<id> = <expr>
A = <expr>
A = <expr> + <term>
A = <term> + <term>
A = <factor> + <term>
A = <id> + <term>
A = B + <term>
A = B + <factor>
A = B + ( <expr> )
A = B + ( <term> * <factor> )
A = B + ( <factor> * <factor> )
A = B + ( <id> * <factor> )
A = B + ( C * <factor> )
A = B + ( C * ( <expr> ) )
A = B + ( C * ( <term> * <factor> ) )
A = B + ( C * ( <factor> * <factor> ) )
A = B + ( C * ( <id> * <factor> ) )
A = B + ( C * ( A * <id> ) )
A = B + ( C * ( A * B ) )
```

**Parse tree**:

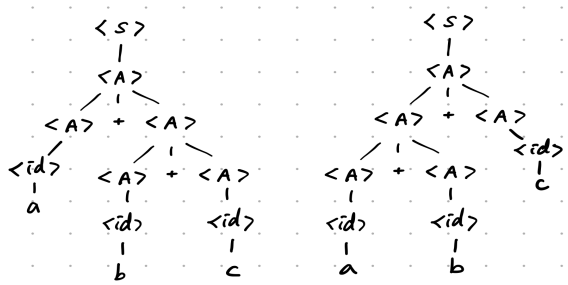



## Q2: Prove Grammar is Ambiguous

The grammar is:

```
<S> → <A>
<A> → <A> + <A> | <id>
<id> → a | b | c
```

the string `a + b + c` can lead to 2 different parse trees:




If the structures of two parse trees are different, it indicate that the grammar is ambiguous.

## Q3: Modify the Grammar to Add Unary Minus and Power Operator

- Precedence order: '()' > `-` > `^` > `*` > `+` .
- Left associativity for `+` and `*` .
- Right associativity for `-` and `^` .

Modified grammar:

```
<assign> → <id> = <expr>
<id> → A | B | C
<expr> → <expr> + <term> | <term>
```

```
<term> → <term> * <factor> | <factor>
<factor> → <unary> ^ <factor> | <unary>
<unary> → - <primary> | <primary>
<primary> → ( <expr> ) | <id>
```