In the following questions, you will define the syntax and semantics of a programming language. Suppose that we have a programming language called PL. Below is given an example PL program. (The example program has no meaning. We are concerned only with the syntax and semantics of the language.)

```
program exampleprogram
  int a,x,count
  real num1,num2
  int i,j
  x=count*int(num1)+5*j
  loop i=1,10,2
    if x=5+a then
      num1=1
      num2=1
    else
      num1=a+x
      loop j=10,20,1
        num2=num2+1
      endloop
    endif
    x=x+1
  endloop
end
```

A program begins with `program` keyword and is given a name, and ends with `end` keyword. First we have variable declarations, then statements. There are two types of variables: integers (int) and real numbers (real). There can be several declarations of the same type in any order. For instance, in the above program, an `int` declaration is followed by a `real` declaration and then by another `int` declaration.

There are three statement types: assignment statement, loop statement and if statement. In an assignment statement, we can use variables, numeric values and the operators + and * (no other operators). When more than one operator is used in an expression, left operator has precedence (i.e. * and + have the same precedence; the operator on the left will be executed first). Also we can use a built-in function `int` which takes a single variable name as parameter and converts it into an integer.

A loop statement has the following syntax: `loop var=init,final,step`, where `var` is a variable and `init`, `final` and `step` are integers. The semantics is as follows: `var` is initialized to `init` (initial value) and the body of the loop is executed. At each iteration, `var` is incremented by `step` (increment value) and the loop terminates when `var > final` (terminating value).

An if statement has a `then` part and an optional `else` part. The boolean condition of an if statement has the same syntax as an assignment statement, i.e. a single variable on the left-hand side and an expression on the right-hand side.

Within the scope of a loop or if statement, any type of statements can exists. For instance, in the above program, the outer loop contains an if statement, which also contains another loop statement. In a program, there must be at least one declaration and one statement. In a loop or if statement, there must be at least one statement.

(continued on next page)
1. Write the BNF description of PL. Do not use EBNF.
   (Note: You do not need to define the variable (identifier) names and numbers.)

2. Specify a low-level language (similar to the language we used in the course) for operational semantics definitions. Then write the operational semantics of the three constructs in the language: assignment statement, loop statement and if statement.
   You will only write the semantics of these constructs; you do not need to give the semantics definitions of the elements in these constructs (e.g. you do not need to define the statements in a loop or the expression in an assignment).

3. Write the denotational semantics of the constructs in the language: assignment statement, loop statement and if statement. You must give a complete semantics definition, i.e. you must define all the functions you use.
   (Note: You can ignore the error checks in the definitions.)

4. Design an attribute grammar for the following constraint: A variable used in a statement must have been declared before in a declaration statement.

Notes:
- Questions 1:25 points, 2:15 points, 3,4:30 points
- Time: 2:00 hours
- Close notes and books

Gün gelecek gülüm, gün gelecek
Kardeş insanlar birbirlerine
Senin gözlerinle bakacaklar gülüm
   Senin gözlerinle bakacaklar.