Answer the following questions in the space provided. The exam has 100 points total, 20 points for each of the five questions. No notes, no book, and no neighbors.

1. Consider the following grammar:

   statement ::= if expr then statement else statement
                 | if expr then statement
                 | id = expr
                 | id ( expr )

   expr ::= id       | expr + id

Rewrite the grammar to be LL(1).

2. What is the follow set for the nonterminal expr?

3. Write a series of recursive descent routines to recognize the nonterminals statement and expr.

4. Although the Venerable Bede knew already in 730 AD that the Julian year was 11 minutes and 14 seconds too long, it was not until 1582 that Pope Gregory XIII approved the rule we now use for determining if a year is a leap year. This rule says that a year is a leap year if it is divisible by 4, unless it is divisible by 100, in which case it is not, unless it is also divisible by 400. We can write this as follows:

   if ((year mod 4 == 0) and (year mod 100 != 0)) or (year mod 400 == 0) then
     printStr("leap year")

show the code our compiler would generate for this statement. Assume year is found at location 4 relative to the frame pointer.
5. Show the control flow graph that would be generated for the following procedure. Assume \( c \) is a 8 by 8 matrix of integer values, indexed from 1 to 8, that begins at offset -100 in the activation record. Then, describe an example optimization of each of the following types that could be performed on this graph:

A. Algebraic transformations
B. Loop invariant code removal
C. Reduction in strength
D. Available expressions

(You don’t need to rewrite the CFG, just tell me what the optimization would do).

\[
\begin{align*}
\text{for } i & := 1 \text{ to } 8 \text{ do} \\
& \quad \text{for } j := 1 \text{ to } 8 \text{ do} \\
& \quad \quad c[i, j] := 0 \\
& \quad c[i, i] = 1
\end{align*}
\]