University of Toronto
Faculty of Arts and Science
April/May 2009 Examinations
CSC488H1S / CSC2107H1S
Duration – 2 hours (120 minutes)
OPEN BOOK ALL written aids, books and notes are allowed.
ALL non-programmable calculators allowed.
NO other electronic aids allowed.

120 marks total, 8 Questions on 4 Pages. ANSWER ALL QUESTIONS
Write all answers in the Exam book.
You must receive a mark of 35% or greater on this final exam to pass the course.

WRITE LEGIBLY Unreadable answers cannot be marked.
Line/rule reference numbers on the left side of of programs and grammars are provided for ease of reference only and are not part of the program or grammar .
The notation `...` stands for correct code that has been omitted for brevity
State clearly any assumptions that you have to make to answer a question.

1. [10 marks] Assume you would like to make the project language a little more programmer friendly and allow all double character terminal symbols to have white space between them. For example, allow `:=` and `: =` , allow `<>` and `< >` .
Describe how you would implement this change in the compiler488 scanner and parser.

2. [10 marks] During the LL(1) table construction algorithm, how is a failure in the LL(1) property detected, i.e. what condition indicates that the grammar is not LL(1)?

3. [15 marks] In some programming languages comments start with the characters `(*` and end with the characters `*)` . Comments may be *nested*. For example:

```
(*    Outer comment which contains
      (*  this inner comment
          which ends here  ->*)
      and the outer comment ends on the next line
*)
```

Describe the lexical analysis algorithms necessary to process nested comments.

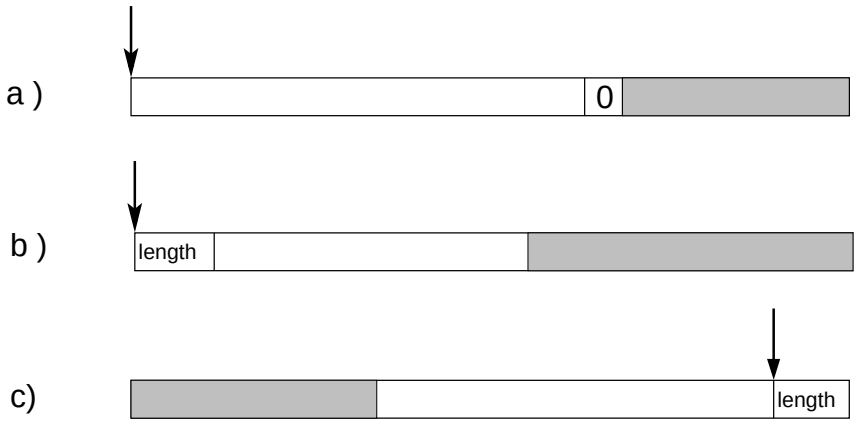
4. [25 marks] The figure below illustrates three different ways of representing fixed length strings (i.e. the maximum length of the string is a constant known to the compiler).

a) C-style null terminated strings.

b) String with an explicit length field at the front.

c) String with an explicit length field at the end.

Where the *length* field contains the current length of the string, 0 stands for a byte containing zero. The arrow indicates the memory address used to access the string. The shaded part of each string represents characters that are unused in the current value of the string (i.e. the current value is shorter than maximum value)



Evaluate and compare each of these representations in terms of ease of implementation of common string operations:

a) string assignment

b) obtaining the length of a string

c) string concatenation, you can assume that tail concatenation (S := S + moreS) is the dominant form of concatenation.

d) obtaining a substring from a larger string

e) passing strings as arguments to functions/procedures that will accept any length string as an argument.

5. [10 marks] Describe the optimizations that a good optimizing compiler would make on the fragment of C code on lines 20 .. 25 .

```
 1    double cubeIt( double X ) {
 2        return X * X * X
 3    }
 4    double squareIt( double X ) {
 5        return X * X
 6    }
 7    double A[ 50 ][ 50 ], B[ 50 ][ 50 ], X[ 50 ] ;
 8    int J, K ;
 9    /* Assume A and B are given values here */
      ...
20    for( J = 0 ; J < 50 ; J ++ )
21      X[ J ] = 0.0 ;
22    for( J = 1 ; J < 50 ; J ++ )
23      for( K = 0 ; K < 50 ; K ++ )
24        X[ J ] = X[ J ] + 7.0 * cubeIt( 2.0 * A[ J ][ K ] )
25                  + 5.0 * squareIt( B[ J ][ K ] * X[ J - 1 ] ) + 3.0 ;
```

6. [10 marks] The following fragment of *legal* C code is known as Duffs device. It is a copy loop that has been unrolled eight times that also efficiently deals with copy lengths that are not multiples of eight.

```
 1     void  duff( char *to, char *from, int count ) {
 2             /* copy count characters */
 3             int n = ( count + 7 ) / 8 ;
 4             switch( count % 8 ) {
 5             case 0:  do  {  *to++ = *from++ ;
 6             case 7:         *to++ = *from++ ;
 7             case 6:         *to++ = *from++ ;
 8             case 5:         *to++ = *from++ ;
 9             case 4:         *to++ = *from++ ;
10             case 3:         *to++ = *from++ ;
11             case 2:         *to++ = *from++ ;
12             case 1:         *to++ = *from++ ;
13                     } while( --n > 0 ) ;
14             }
15         }
```

Show the basic blocks for this function
Show the control flow graph for this function

7. [20 marks] The TYPECASE statement in the statically typed Modula-3 programming language has the form:

Definition	Example
TYPECASE Expr OF T_1 (v_1) => S_1 | T_2 (v_2) => S_2 | ... | T_n (v_n) => S_n ELSE S_0 END	PROCEDURE ToText(r : REFANY) : TEXT = (* Assume r = NIL or r^ is a BOOLEAN or INTEGER *) BEGIN TYPECASE r OF NULL => RETURN "NIL" | REF BOOLEAN (rb) => RETURN Fmt.Bool(rb^) | REF INTEGER (ri) => RETURN Fmt.Int(ri^) END END ToText

Where *Expr* is an expression whose type is a *REF ANY* type (e.g. like **void ***), the S_i are statements, the T_is are specific reference types, and the v_i are identifiers. The ^ operator indicates pointer dereferencing, *REF type* is a pointer to *type*. The ELSE part and the (v_i) parts are optional.

The TYPECASE statement evaluates *Expr*. If the resulting reference value is a member of any listed type T_i then S_i is executed for the minimum such i. If the value of *Expr* is a member of no listed type and ELSE S_0 is present then S_0 is executed otherwise a runtime error occurs. Each v_i declares a variable whose type is T_i and whose scope is S_i. If v_i is present it is initialized to the value of *Expr* before S_i is executed.

a) Describe a set of static semantic analysis checks that should be applied to this statement.

b) Describe how you would implement this statement. You can use pseudo-code or diagrams in your answer. Include all runtime mechanisms that you require.

8.[20 marks] Design a *recursive descent* parser function for the TYPECASE statement in the previous question. You may assume the existence of functions that recognize *statement*, *types* and *expressions*. The function you are writing will be called when the statement parsing function recognizes the terminal symbol for TYPECASE as its next input token. Your function should parse one entire TYPECASE statement and return success or failure. Describe any assumptions you make in your solution.