

Concepts of Programming Languages, CSCI 305, Fall 2020
Exam 4, Nov. 20

Name _____

This is a closed book exam. You may not use notes, the text book, Internet, etc.

1. The static data in a C program is given a layout. At what time did that data get bound to a specific layout? (4 pts.)
 - a. Language design time
 - b. Compile time
 - c. Link time
 - d. Load time
 - e. Run time

2. The total amount of space occupied by a program code and data is most likely to be bound at what time? (4 pts.)
 - a. Language implementation time
 - b. Compile time
 - c. Link time
 - d. Load time
 - e. Run time

3. In C the data type integer is allowed to have a certain range of values. At what time are integers bound to this range? (4 pts.)
 - a. Language design time
 - b. Language implementation time
 - c. Compile time
 - d. Load time
 - e. Run time

4. In what part of memory are scalar variables most likely to be stored when a program is executing? (4 pts.)
 - a. Static storage
 - b. Stack storage
 - c. Heap storage
 - d. All of the above
 - e. None of the above

5. In what part of memory are machine instructions most likely to be stored when a program is executing? (4 pts.)
 - a. Static storage
 - b. Stack storage
 - c. Heap storage
 - d. Any of the above
 - e. None of the above

6. Consider the following pseudo code

```
x : integer -- global
```

```
procedure set_x(n : integer)
```

```
  x:=n
```

```
procedure print_x()
```

```
  write_integer(x)
```

```
procedure first()
```

```
  set_x(1)
```

```
  print_x()
```

```
procedure second()
```

```
  x : integer
```

```
  set_x(2)
```

```
  print_x()
```

```
set_x(0)
```

```
first()
```

```
print_x()
```

```
second()
```

```
print_x()
```

a. What does this program print if the language uses static scoping? (3 pts.)

b. What does it print if the language uses dynamic scoping? (2 pts.)

7. You have been hired by a company which develops air traffic control systems. Due to the real-time and highly complex nature of these systems, they have decided to create an in-house, specialized programming language, to be used in the development of all of their systems. This language is meant to be highly modular and allows nested subroutines. Your team is in the process of deciding whether the language uses static or dynamic scope. They have asked you to describe the difference. Write your response. (3 pts.)

Your response was so helpful and clear that they now want you to make a recommendation of which scope to use and why. Write your response. (2 pts.)

8. The following grammar parses strings in the language $\{a^n b^m c^k \mid n, m, k \geq 0\}$.
Example strings in this language are ϵ , acc , b , $aaaabcc$, $aaabbbccc$.

$abcString \rightarrow alist\ blist\ clist\ \$$
 $alist \rightarrow a\ alist$
 $alist \rightarrow \epsilon$
 $blist \rightarrow b\ blist$
 $blist \rightarrow \epsilon$
 $clist \rightarrow c\ clist$
 $clist \rightarrow \epsilon$

Create an attribute grammar for this grammar which gives the length of the string to the root. (5 pts.)

$abcString \rightarrow alist\ blist\ clist\ \$$

$alist_1 \rightarrow a\ alist_2$

$alist \rightarrow \epsilon$

$blist_1 \rightarrow b\ blist_2$

$blist \rightarrow \epsilon$

$clist_1 \rightarrow c\ clist_2$

$clist \rightarrow \epsilon$

9. Write a BNF or regular expression description for financial quantities which begin with dollar sign (\$), contain a number, decimal point (.) and two decimal digits.

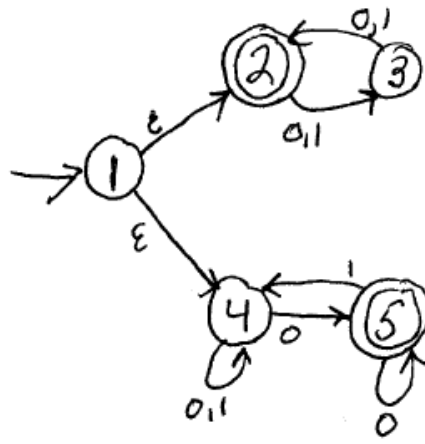
The number must be at least one character but has no maximum number of characters. The number contains thousand, million, billion, etc. dividers. The number can be 0, but if it is not 0, it cannot contain leading 0s.

Negative financial quantities are not allowed and the decimal portion is required.

(10 pts.)

Legal Financial Quantities	Illegal Financial Quantities
\$0.00	0.00
\$0.59	\$139
\$2,546,000.99	\$04.99
\$99.01	\$.75

10. Use the construction described in class and the text to convert the following nondeterministic finite automaton (NFA) to an equivalent deterministic finite automaton (DFA). (4 pts.)



Describe the strings which are accepted by the NFA above. (1 pt.)

11. Extend the grammar below to include if statements and while loops, along the lines suggested by the following examples:

```
abs := n
if n < 0 then abs := 0 - abs fi
```

```
sum := 0
read count
while count > 0 do
  read n
  sum := sum + n
  count := count - 1
od
write sum
```

Your grammar should support the six standard comparison operations (<, <=, >, >=, ==, !=) in conditions, with arbitrary expressions as operands. It also should allow an arbitrary number of statements in the body of an 'if' statement or 'while' statement.

(10 pts)

1. program \rightarrow stmt_list \$\$
2. stmt_list \rightarrow stmt stmt_list
3. stmt_list \rightarrow stmt
4. stmt \rightarrow id := expr
5. stmt \rightarrow read id
6. stmt \rightarrow write expr
7. expr \rightarrow term
8. expr \rightarrow expr add_op term
9. term \rightarrow factor
10. term \rightarrow term mult_op factor
11. factor \rightarrow (expr)
12. factor \rightarrow id
13. factor \rightarrow number
14. add_op \rightarrow +
15. add_op \rightarrow -
16. mult_op \rightarrow *
17. mult_op \rightarrow /

12. The following grammar has a single variable S and two terminals 0 and 1.

$$S \rightarrow 0 S 1$$
$$S \rightarrow 01$$

Tell if this grammar is LL(1), and if not, convert it into an LL(1) grammar.

(5 pts)

13. Define what is meant by orthogonality in the context of programming languages.

(5 pts.)

14. The grammar

$$\begin{aligned} S &\rightarrow E \$ \\ E &\rightarrow E + T \mid T \\ T &\rightarrow T * F \mid F \\ F &\rightarrow (E) \mid \text{id} \end{aligned}$$

can be adapted for top-down parsing as follows:

1. $S \rightarrow E \$$
2. $E \rightarrow T E'$
3. $E' \rightarrow + T E' \mid \epsilon$
4. $E' \rightarrow \epsilon$
5. $T \rightarrow F T'$
6. $T' \rightarrow * F T' \mid \epsilon$
7. $T' \rightarrow \epsilon$
8. $F \rightarrow (E) \mid \text{id}$
9. $F \rightarrow \text{id}$

This adapted grammar has the LL parsing table:

	+	*	()	id	\$
S	-	-	1	-	1	-
E	-	-	2	-	2	-
T	-	-	5	-	5	-
E'	3	-	-	4	-	4
F	-	-	8	-	9	-
T'	7	6	-	7	-	7

```

terminal = 1 .. number_of_terminals
non_terminal = number_of_terminals + 1 .. number_of_symbols
symbol = 1 .. number_of_symbols
production = 1 .. number_of Productions

parse_tab : array [non_terminal, terminal] of record
    action : (predict, error)
    prod : production
prod_tab : array [production] of list of symbol
-- these two tables are created by a parser generator tool

parse_stack : stack of symbol

parse_stack.push(start_symbol)
loop
    expected_sym : symbol := parse_stack.pop()
    if expected_sym ∈ terminal
        match(expected_sym)           -- as in Figure 2.17
        if expected_sym = $$ then return -- success!
    else
        if parse_tab[expected_sym, input_token].action = error
            parse_error
        else
            prediction : production := parse_tab[expected_sym, input_token].prod
            foreach sym : symbol in reverse prod_tab[prediction]
                parse_stack.push(sym)

```

Using the above LL parsing code, the parsing table and productions given previously, walk through the parse of the string

a + a * b \$

clearly showing every item that is push and popped from the parsing stack.

(10 pts.)

14. Complete the grid to contrast the imperative, functional and logic languages.
(10 pts.)

	Imperative	Functional	Logic
Basis			
Computes principally using			

Write code in Prolog for the following. Do not use the computer, simply write your program onto the test page.

15. Write Prolog code to reverse a list. So that

?- my_reverse([a, b, c, d],X).

X = [d, c, b, a].

(5 pts.)

SWI Prolog contains a reverse function, however, do not use this in your answer.

Might be helpful: The Prolog relation append is a set of tuples of the form (X,Y,Z), where Z consists of the elements of X followed by the elements of Y.

Example: ([a],[b],[a, b]) is in the relation append.

16. In the Prolog version of the Tic-Tac-Toe game, given in lab and the text, the user is 'o' and the computer is 'x'. The AI for selecting the computer's move follows:

```
% Strategy
good(A) :- win(A).
good(A) :- block_win(A).
good(A) :- split(A).
good(A) :- strong_build(A).
good(A) :- weak_build(A).
good(5).
good(1).
good(3).
good(7).
good(9).
good(2).
good(4).
good(6).
good(8).

win(A) :- x(B), x(C), line(A,B,C).
block_win(A) :- o(B), o(C), line(A,B,C).
split(A) :- x(B), x(C), different(B, C),
           line(A,B,D), line(A,C,E), empty(D), empty(E).
strong_build(A) :- x(B), line(A,B,C), empty(C), \+(risky(C)).
weak_build(A) :- x(B), line(A,B,C), empty(C), \+(double_risky(C)).
risky(C) :- o(D), line(C,D,E), empty(E).
double_risky(C) :- o(D), o(E), different(D, E),
                  line(C,D,F), line(C,E,G), empty(F), empty(G).
```

Say that have chosen to first. Give a sequence of moves that eventually cause the rules

```
good(A) :- win(A).
good(A) :- block_win(A).
good(A) :- split(A).
```

to fail, but the rule

```
good(A) :- strong_build(A).
```

to succeed.

(3 pts.)

Describe how the rule

```
good(A) :- strong_build(A).
```

succeeds.

(2 pts.)

Extra Credit

17. If we curry $f(x, y, z)$ into $f(x)(y)(z)$; what does $f(x)$ return? (1 pt.)
- a. Nothing
 - b. An integer
 - c. A function that takes a single parameter
 - d. A pointer
18. Currying allows for more than the required number of parameters (1 pt.)
- a. True
 - b. False
19. What does exception handling NOT do? (1 pt.)
- a. Propagate errors up the call stack
 - b. Group error types and error differentiation
 - c. Separate error handling code from “regular” code
 - d. Contain resource leaks from unhandled exceptions
20. Which of the following is not a type of loop improvement? (1 pt.)
- a. Interchange
 - b. Prototyping
 - c. Induction Variables
 - d. Unswitching
21. In call by sharing, what determines whether or not a parameter is passed a value or a reference? (1 pt.)