Midterm Exam
CS 314, Fall '17
October 27
SAMPLE SOLUTION

DO NOT OPEN THE EXAM UNTIL YOU ARE TOLD TO DO SO

Name: ______________________________

Rutgers ID number: ______________________________

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Section: _____

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WRITE YOUR NAME ON EACH PAGE IN THE UPPER RIGHT CORNER

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Instructions

We have tried to provide enough information to allow you to answer each of the questions. If you need additional information, make a *reasonable* assumption, write down the assumption with your answer, and answer the question. There are **5** problems, and the exam has **8** pages. Make sure that you have all pages. The exam is worth **250** points. You have **80 minutes** to answer the questions. Good luck!

This table is for grading purposes only

1	/ 80
2	/ 60
3	/ 30
4	/ 20
5	/ 60
total	/ 250

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Problem 1 – Regular Expressions, DFA and Context Free Grammars (80 pts)

The context-free grammar `G` is specified in Backus-Naur-Form as follows, with `D` as the start symbol:

```
1: D ::= a D |
2:       b E
3: E ::= b E |
4:       F
5: F ::= c
```

1. Give a leftmost derivation ($\Rightarrow_L$) for the string $\boxed{\texttt{a b c}}$ given the grammar above. (15 pts)

   D $\Rightarrow_L$ aD $\Rightarrow_L$ abE $\Rightarrow_L$ abF $\Rightarrow_L$ abc

2. Give the LL(1) parse table for the grammar `G`. **Insert the rule number or leave an entry empty**.(35 pts)

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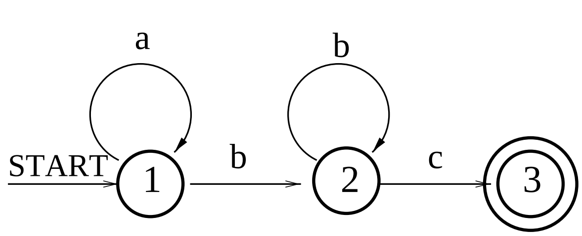
	a	b	c	eof
F			5	
E		3	4	
D	1	2		

3. Give a regular expression for the language generated by the grammar `G`. (15 pts)

   a^*b^+c

4. Specify a DFA by extending the state transition diagram below. The start state is **state 1**, and the final (accepting) state is **state 3**. You are only allowed to add edges with their appropriate labels, i.e., valid labels are *a*, *b*, and *c*. Note that an edge may have more than one label. You **must not** add any states. (15 pts)



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Problem 2 – Context Free Grammars (60 pts)

A *context-free language* is a language that can be specified using a context-free grammar. A *regular* language is a language that can be specified using a regular expression.

For the three languages given below, if the language is context-free, give a compact context-free grammar in Backus-Naur-Form (BNF). If the language is regular, give a compact regular expression using the regular expression syntax introduced in class. If a language is context-free and regular, give both specifications, a BNF and a regular expression. You do not have to justify why you believe a language is not context-free or not regular.

1. { $0^n 1^{3n}$ | n ≥ 0 }, with alphabet Σ = {0, 1}

   S ::= 0S111 | ϵ

2. { $a^n b^{3m} c^n$ | n ≥ 0, m >0 }, with alphabet Σ = {a, b, c}

   S ::= aSc | B

   B::= bbbB | bbb

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3. { w | w has at least 2 symbols, but no more than 5}, with alphabet Σ={0, 1}

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   S ::= A A B B B

   A ::= 0 | 1

   B ::= 0 | 1 | ϵ

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   Regular expression: (0 | 1) (0 | 1) (0 | 1 | ϵ) (0 | 1 | ϵ) (0 | 1 | ϵ)

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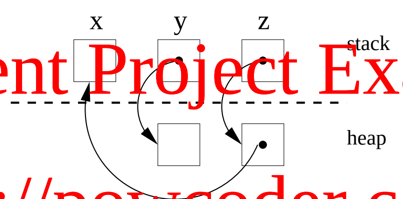
Problem 3 – Pointers and Memory Allocation in C (30 pts)

```
int main() {
  int   x;
  int  *y;
  int **z;

  z = (int **) malloc (sizeof(int *));
  y = (int *) malloc (sizeof(int));
  x = 3;
  *z = &x;
  *y = x;
  x = x + 3;
  **z = *y + 5;
  printf("x=%d, *y=%d, **z=%d\n", x, *y, **z);
  return 0;
}
```



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1. What is the output of the above program? (3 pts each)

   x= 8, *y= 3, **z= 8

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2. Specify, whether the following program objects are allocated on the **stack** (includes global variables), on the **heap**, or **not defined** (2 pts each).

   *x is allocated on the not defined

   *y is allocated on the heap

   z is allocated on the stack

   x is allocated on the stack

   y is allocated on the stack

   *z is allocated on the heap

   **y is allocated on the not defined

   **z is allocated on the stack

3. Assume the following code segment:

   ```
   int *x;
   *x = 5;
   printf("%d\n", *x);
   ```

   Is there a problem with this code? Assume that when you ran the code a couple of times, it printed “5”. If you believe there is a problem, give a possible “fix” for the problem? (5 pts)

The content of variable `x` is not initialized. However, its content is used as an address of a memory location, and that memory location is assigned the value `5`.

To fix the problem, the pointer `x` should be initialized to `NULL` in its declaration, and `x` must point to an object on the heap before it is dereferenced. This object is allocated as follows:

```
x = (int *) malloc(sizeof(int *))
```

This statement should be placed before statement `*x = 5`, i.e., before the dereference operation on `x`.

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Problem 4 – Compilers vs. Interpreters (20 pts)

To answer this question, please use the following definitions.

Definition A <u>**compiler**</u> maps an input program to a semantically equivalent output program. Note that the input and output language may be the same. □

Definition An <u>**interpreter**</u> maps an input program to the answers it computes; In other words, it executes the program. □

As part of the C project, we used and/or wrote the following programs/commands:

- gcc – *usage*: gcc <program>
- compile – *usage*: compile <program>
- constfolding – *usage*: constfolding < <program>
- sim – *usage*: sim <program>

Under Unix/Linux, commands can be entered on a single command line if they are separated by a semicolon. For instance, saying `cd foo; ls` will change the current directory to subdirectory `foo`, and will list its files.

In the project, we used several languages, namely C, tinyL, RISC machine code and ilab machines object code (executables). **Classify the following commands or the entire sequence of commands** as either compiler or interpreter. Note that you should treat a sequence of commands as a single unit, i.e., as a single composed command. If the single or composed command is a compiler, give its input and output language (e.g.: input language: C, output language: tinyL). For an interpreter, just give its input language.

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1. `compile test1`

   Answer (mark one): compiler: [X] or interpreter [ ]

   input language: <u>tinyL</u>, output language: <u>ILOC RISC machine code</u>

2. `compile test1; sim tinyL.out`

   Answer (mark one): compiler: [ ] or interpreter [X]

   input language: <u>tinyL</u>, output language: ______________

3. `gcc Compiler.c`

   Answer (mark one): compiler: [X] or interpreter [ ]

   input language: <u>C</u>, output language: <u>ilab machine code (executable)</u>

4. `constfolding < tinyL.out`

   Answer (mark one): compiler: [X] or interpreter [ ]

   input language: <u>ILOC RISC machine code</u>, output language: <u>ILOC RISC machine code</u>

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Problem 5 – Syntax-Directed Translation (60 pts)

Assume the following partial expression grammar:

<expr> ::= + <expr> <expr> |
$\quad\quad\quad\quad$ $*$ <expr> <expr> |
$\quad\quad\quad\quad$ <const>
<const> ::= 1 | 2

instr. format	description	semantics
memory instructions		
`loadI` <const> $\Rightarrow_L$ r_x	load constant value <const> into register r_x	$r_x \leftarrow$ <const>
arithmetic instructions		
`add` r_x , r_y $\Rightarrow_L$ r_z	add contents of registers r_x and r_y , and store result into register r_z	$r_z \leftarrow r_x + r_y$
`mult` r_x , r_y $\Rightarrow_L$ r_z	multiply contents of registers r_x and r_y , and store result into register r_z	$r_z \leftarrow r_x * r_y$

Here is a recursive descent parser that implements a compiler for the above grammar. Here is the important part of the code:

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```
int expr() {
        int reg, left_reg, right_reg;
        switch (token) {
        case '+': next_token();
                  left_reg = expr(); right_reg = expr(); reg = next_register();
                  CodeGen(ADD, left_reg, right_reg, reg);
                  return reg;
        case '*': next_token();
                  left_reg = expr(); right_reg = expr(); reg = next_register();
                  CodeGen(MULT, left_reg, right_reg, reg);
                  return reg;
        case '1':
        case '2': return const();
        }
}

int const() {
        int reg;
        switch (token) {
        case '1':  next_token(); reg = next_register();
                   CodeGen(LOADI, 1, reg);
                   return reg;
        case '2': next_token(); reg = next_register();
                   CodeGen(LOADI, 2, reg);
                   return reg;
        }
}
```

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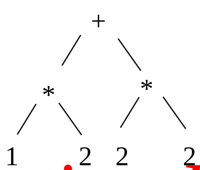
Make the following assumptions:

- The value of variable “token” has been initialized correctly.
- The function `CodeGen` is the one from our first project.
- **The first call to function `next_register()` the shown parser returns integer value “1”.** In other words, the first register that the generated code will be using is register r_1.
- Your parser “starts” by calling function `expr()` on the entire input.

1. Show the code that the recursive descent parser generates for input

   `+ * 1 2 * 2 2`

   will produce:



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loadI 1 ⇒ r1
loadI 2 ⇒ r2
mult r1, r2 ⇒ r3
loadI 2 ⇒ r4
loadI 2 ⇒ r5
mult r4, r5 ⇒ r6
add r3, r6 ⇒ r7

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2. Change the basic recursive-descent parser to implement an interpreter for our example language. You may insert pseudo code in the spaces marked by ________. No error handling is necessary.

```
  int  expr() {

        int a, b;
        switch (token) {
        case '+': next_token();
                       a = expr(); b = expr();
                  return (a + b);

        case '*': next_token();
                       a = expr(); b = expr();
                  return (a * b);

        case '1':
        case '2': return const();
        }
}

  int  const() {

        switch (token) {
        case '1':  next_token();
                   return 1 ;

        case '2':  next_token();
                   return 2 ;
        }
}
```

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