

CMSC 330, Fall 2018 — Final

NAME _____

TEACHING ASSISTANT

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INSTRUCTIONS

- Do not start this exam until you are told to do so.
- You have 120 minutes for this exam.
- This is a closed book exam. No notes or other aids are allowed.
- For partial credit, show all your work and clearly indicate your answers.

HONOR PLEDGE

Please copy and sign the honor pledge: “I pledge on my honor that I have not given or received any unauthorized assistance on this examination.”

Section	Points
Programming Language Concepts	8
λ -Calculus	8
OCaml	28
Ruby	13
Rust	17
Regex, FA, CFG	20
Parsing	10
Operational Semantics	6
Security	10
Total	120



1 Programming Language Concepts

1. [1 pts] (T / F) Both Rust and OCaml allow a programmer to manually manage memory.
2. [1 pts] (T / F) Reference counting garbage can collect cyclic dead objects.
3. [1 pts] (T / F) Traits in Rust are analogous to interfaces in Java.
4. [1 pts] (T / F) Languages that perform “bounds checking,” like Java, on read or write attempts are less vulnerable to buffer overflow attacks than ones that don’t (such as C).
5. [2 pts] Circle all of the following programming language features that Ruby has:

(a) Dynamic Typing (b) Static Typing (c) Lexical Scoping (d) Dynamic Scoping
6. [2 pts] Given the definitions of `fold_left` and `fold_right` below, which function would you use if you were trying to sum a list of one million elements and why? Be brief.

```
let rec fold_left f a xs =  
  match xs with  
  | [] -> a  
  | x :: xt -> fold_left f (f a x) xt
```

```
let rec fold_right f xs a =  
  match xs with  
  | [] -> a  
  | x :: xt -> f x (fold_right f xt a)
```



2 λ -Calculus

1. Circle T if the expressions are α -equivalent and F otherwise.

(a) [1 pts] (T / F) $(\lambda y. y) y$ $\lambda y. y y$

(b) [1 pts] (T / F) $(\lambda y. y) y$ $(\lambda x. x) x$

2. [2 pts] Write a λ expression that has no normal form.

3. [4 pts] Reduce the λ expression to β -normal form (to be eligible for partial credit, show each reduction step). If already in normal form, write “normal form.” If it reduces infinitely, write “reduces infinitely.”

$(\lambda x. (\lambda x. x x)) a (\lambda y. y) c$



3 OCaml

You may use `map`, `fold_left`, and `fold_right` on any of the following questions.

1. [8 pts] The `unfoldr` function generates a list of values from a function (the generator) and an initial value (the seed). The generator returns `'a * 'b option`, and should be called repeatedly to build up the list. When the generator returns `None`, the list is finished. When it returns `Some`, the first value of the tuple should be added to the list, and the second value of the tuple should be used as the next seed.

```
let f seed = if seed <= 4 then Some (seed, seed + 1) else None
unfoldr f 1 = [1; 2; 3; 4]
unfoldr f 3 = [3; 4]
```

Implement `unfoldr` below.

```
let rec unfoldr (f : 'a -> ('b, 'a) option) (seed : 'a) : 'b list =
```

2. [5 pts] The Iverson bracket function converts a predicate into a function that returns 0 if the predicate is not satisfied and 1 if it is.

```
let even_pred x = (x mod 2) = 0
let even_iver = iver even_pred
```

Given the above, `even_iver 4 = 1` and `even_iver 5 = 0`. Implement `iver` below.

```
let iver (p : ('a -> bool)) : ('a -> int) =
```



3. [10 pts] The prime-counting function `prime_count` returns the number of primes less than or equal to n . Assuming there exists a predicate `prime` that determines if a number is prime, implement `prime_count` **without** making `prime_count` itself recursive. You will receive at most $\frac{1}{2}$ credit if you make `prime_count` itself recursive. (Hint: Use `unfoldr` and `iver` above).

```
let prime_count (n : int) : int =
```

4. [5 pts]

```
type 'a non_empty_list =  
  | End of 'a  
  | Cons of ('a * 'a non_empty_list)
```

Given the above type declaration of `non_empty_list`, write a function `length` that calculates the length of a `non_empty_list` `l`.

```
length (End 1) = 1  
length (Cons ('d', Cons ('u', Cons ('c', End 'k')))) = 4
```

Implement `length` below.

```
let rec length (l : non_empty_list) : int =
```



4 Ruby

The school's rubber duck population has been getting out of hand. You have been tasked with writing software in order to bring it under control. On the next page, implement the class `DuckSorter` that will read a text file and allow you to search for duck's with a given attribute.

1. [7 pts] Implement the `initialize` method that takes a filename then reads and stores the information about the rubber ducks in a data structure of your choice. If a duck's name appears multiple times in the file, the attribute list should be combined together. If a line is malformed, it should be ignored.
2. [2 pts] Implement the `attributes` method that takes a duck's name and returns an array of all that duck's attributes. Order doesn't matter, but every element in this list should be unique. You may assume that the duck exists.
3. [4 pts] Implement the `search` method that takes a string as an argument containing a single attribute and returns an array of rubber duck names where every duck in the array has the given attribute. Order doesn't matter. If no ducks contain the given attribute, an empty array should be returned.

Here is an example of an input file called `ducks.txt`:

```
name: Fenton, attributes: large, winter
name: Santa, attributes: winter, red, hat
name: Edward, attributes: small, glasses
name: Fenton, attributes: large, blue
```

All names will begin with a capital letter and be followed by lowercase letters. An attribute will be all lowercase and attributes will be separated by a comma and a space. Each line of the text file will have a duck name and a list of attributes. Here is an example of a program using the above methods.

```
a = DuckSorter.new("ducks.txt")
puts a.get_attributes("Fenton").inspect
puts a.search("winter").inspect
puts a.search("large").inspect
```

This will output:

```
["large", "winter", "blue"]
["Fenton", "Santa"]
["Fenton"]
```



```
class DuckSorter
  def initialize(filename)

    IO.foreach(filename) { |line|

    }

  end

  def get_attributes(name)

  end

  def search(attribute)

  end

end
end
```



5 Rust

1. [3 pts]

```
fn quack(s1 : String) -> () {
    {
        let s2 = &s1;
        let s3 = &s1;
    }
    let s4 = s1;
    let s5 = s4;
    let s6 = &s5;
    let s7 = s5;
    let s8 = &s7;
    // HERE
}
```

Who is the owner of the data from `s1` at `HERE`?

2. The following programs have an error. Rewrite the code next to the snippet so there is no error.

(a) [3 pts]

```
fn quack(s1 : String) -> () {
    s1.push_str(" QUACK");
    println!("Duck says: {}", s1);
}
```

(b) [4 pts]

```
fn shortest(x : &str, y : &str) -> &str {
    if x.len() < y.len() { x } else { y }
}
```



3. [7 pts] For the given `Duck` struct, write a function `oldest` that takes an immutable reference to a vector of `Duck` and returns a reference to the oldest one. You may get an `Iterator` from a vector via a call to its `iter` function. You may also assume the input vector is non-empty.

```
struct Duck {  
    name: String,  
    age: i32  
}
```

```
fn oldest (ducks : &Vec<Duck>) -> &Duck {
```

```
}
```



6 Regexp, FA, CFG

- [3 pts] Write a regular expression that describes all the strings over the alphabet $\{d, u, c, k\}$ where u appears exactly once.
- [3 pts] Draw an NFA that is equivalent to the regular expression: $(d | u)^*(ck)^*$
- [5 pts] Write a CFG that accepts strings of the form $d^a u c k^b s$ where $a = b + 1$ and $a, b \geq 1$.
- [3 pts] Write a regular expression that accepts the same set of strings as the following CFG. If this is not possible, explain.

$$S \rightarrow AB$$

$$A \rightarrow Aquack | quack$$

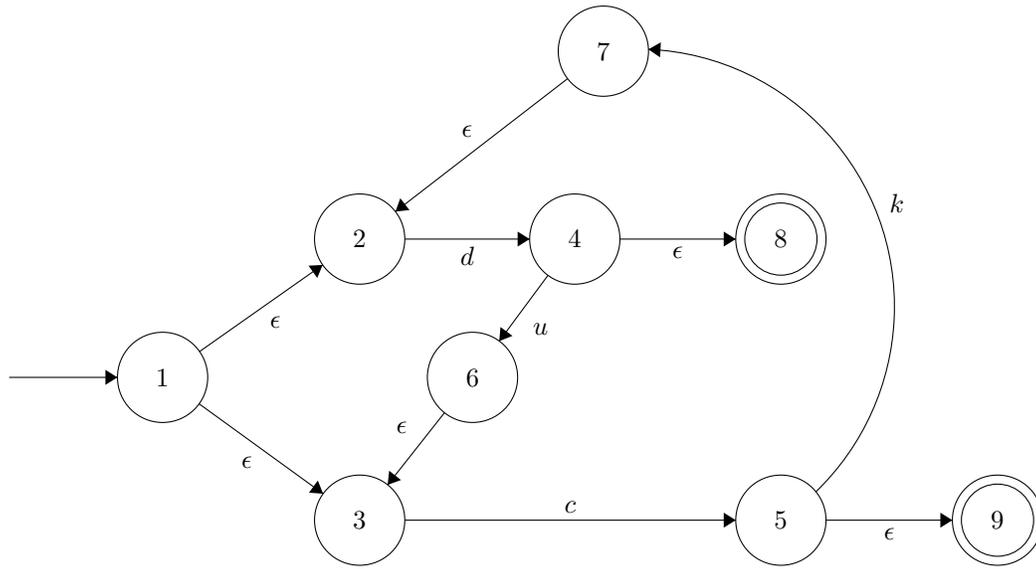
$$B \rightarrow X | Y$$

$$X \rightarrow duX | \varepsilon$$

$$Y \rightarrow ckY | \varepsilon$$



5. [6 pts] Convert the following NFA to a DFA.



7 Parsing

1. Refer to the following ambiguous grammar for the next two questions:

$$S \rightarrow S + S \mid a$$

(a) [1 pts] Identify why the grammar is ambiguous (you do not have to prove with derivations).

(b) [2 pts] Modify the grammar so that it is no longer ambiguous without changing what strings the language accepts.

2. S-expressions are a notation used to represent list and tree-like data. Refer to the following S-expression grammar for the next two questions:

$$S \rightarrow (S.S) \mid [L] \mid n$$

$$L \rightarrow SL \mid \varepsilon$$

(a) [2 pts] What are the first sets for the nonterminals in the grammar?

$$\text{FIRST}(S) = \{ \quad \quad \quad \}$$

$$\text{FIRST}(L) = \{ \quad \quad \quad \}$$

(b) [5 pts] Finish the definition of a recursive descent parser for S-expressions on the next page. You need not build an AST, assume all methods return unit. Note that you are provided the functions `match_tok : string -> unit` and `lookahead : unit -> string`.



For reference, here is the grammar again.

$$S \rightarrow (S.S) \mid [L] \mid n$$

$$L \rightarrow SL \mid \varepsilon$$

Fill in `parse_S` and `parse_L` below.

```
let lookahead () : string =  
  match !tok_list with  
  | [] -> raise (ParseError "no tokens")  
  | h::t -> h
```

```
let match_tok (a : string) : unit =  
  match !tok_list with  
  | h::t when a = h -> tok_list := t  
  | _ -> raise (ParseError "bad match")
```

```
let rec parse_S () : unit =
```

```
and parse_L () : unit =
```



8 Operational Semantics

1. [4 pts] Using the rules given below, show: $A; \text{if } 5 > 3 \text{ then } 3 - 2 \text{ else } 5 - 1 \Rightarrow 1$

$A; \text{false} \Rightarrow \text{false}$	$A; \text{true} \Rightarrow \text{true}$
$A; n \Rightarrow n$	$\frac{A(x) = v}{A; x \Rightarrow v}$
$\frac{A; e_1 \Rightarrow n_1 \quad A; e_2 \Rightarrow n_2 \quad v \text{ is } n_1 > n_2}{A; e_1 > e_2 \Rightarrow v}$	$\frac{A; e_1 \Rightarrow n_1 \quad A; e_2 \Rightarrow n_2 \quad n_3 \text{ is } n_1 - n_2}{A; e_1 - e_2 \Rightarrow n_3}$
$\frac{A; e_1 \Rightarrow \text{true} \quad A; e_2 \Rightarrow v}{A; \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \Rightarrow v}$	$\frac{A; e_1 \Rightarrow \text{false} \quad A; e_3 \Rightarrow v}{A; \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \Rightarrow v}$

$$\frac{}{A; \text{if } 5 > 3 \text{ then } 3 - 2 \text{ else } 5 - 1 \Rightarrow 1}$$

2. [2 pts]

$A; n \Rightarrow n$	$\frac{A(x) = v}{A; x \Rightarrow v}$
$\frac{A; e_1 \Rightarrow v_1 \quad A, x : v_1; e_2 \Rightarrow v_2}{A; \text{let } x = e_1 \text{ in } e_2 \Rightarrow v_2}$	$\frac{A; e_1 \Rightarrow n_1 \quad A; e_2 \Rightarrow n_2 \quad n_3 \text{ is } n_1 + n_2}{A; e_1 + e_2 \Rightarrow n_3}$

Use the above rules to fill in the given construction:

$$\frac{A, x = 4, y = 5, x = 3 \quad (x) = \boxed{}}{A, x = 4, y = 5, x = 3; x \Rightarrow \boxed{}} \quad \frac{A, x = 4, y = 5, x = 3; (y) = 5}{A, x = 4, y = 5, x = 3; y \Rightarrow 5} \quad \boxed{}$$

$$A, x = 4, y = 5, x = 3; x + y \Rightarrow \boxed{}$$



9 Security

1. [1 pts] (T / F) A web application is protected from SQL injections by SQL prepared statements.
2. [1 pts] (T / F) If a language is statically typed, the compiler prevents buffer overflows.
3. [1 pts] (T / F) An XSS vulnerability allows an attacker to execute shell commands on a server.
4. [1 pts] Briefly describe how you would prevent an XSS attack.
5. [2 pts] What are the two different types of XSS attack? What is the difference between them?

6. DUCK Corp. has written this fantastic server:

```
puts "Welcome to the DUCK Corp. Terminal."  
puts "Do well on your CMSC 330 final to get in."  
while true do  
  puts "Enter file in the current directory to view: "  
  file = gets.chomp  
  if file =~ /\.\.\/  
    print "You can only view files in the current directory."  
  else  
    `cat #{file}` # runs shell command cat  
  end  
end
```

- (a) [1 pts] Name the vulnerability that exists in this code.
- (b) [1 pts] Name a fix that could prevent this vulnerability.
- (c) [2 pts] Enter a user input that could cause damage to the DUCK Corp.

