Name:
_________________________________

Discussion Time: 10am 11am 12pm 1pm 2pm 3pm

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Instructions
- Do not start this test until you are told to do so!
- You have 75 minutes to take this midterm.
- This exam has a total of 100 points, so allocate 45 seconds for each point.
- This is a closed book exam. No notes or other aids are allowed.
- Answer essay questions concisely in 2-3 sentences. Longer answers are not needed.
- For partial credit, show all of your work and clearly indicate your answers.
- Write neatly. Credit cannot be given for illegible answers.

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1. Programming Language Concepts (13 pts)

A. (4pts) What will be the value of \( y \) in the following block of OCaml code, first evaluated with static scoping, and then re-evaluated with dynamic scoping:

\[
\begin{align*}
\text{let } x &= 10 ;; \\
\text{let } f &= \\
& \quad \text{let square } y = x \times x \text{ in} \\
& \quad \text{let } x = 20 \text{ in} \\
& \quad \text{square } x ;; \\
\text{let } y &= f ;;
\end{align*}
\]

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Solution:
Static: 100
Dynamic: 400

B. (2pts) Name an advantage and a disadvantage of using an interpreted language: (One sentence answer for each of advantage and disadvantage)

Many options here, e.g.
- Fast to write/iterate on code
- Code runs more slowly than compiled languages
- Code may be more portable (don’t need to recompile)

C. (1pt) One of the most important features of functional programming languages is

a) **Immutable data structures**
b) Statements with side effects
c) Iterative control structures
d) Implicit type definition

D. (1pt) Which is a true statement about lists in Ruby and OCaml?

a) Ruby lists are heterogeneous; OCaml lists are homogenous.
b) Ruby lists are homogenous; OCaml lists are heterogeneous.
c) Ruby lists and OCaml lists are heterogeneous.
d) Ruby lists and OCaml lists are homogenous.

E. (1pt) Which of the following OCaml features is only possible because of closures:

a) Tail Recursion
b) Type Inference
c) **Partial Application**
d) Pattern Matching

F. (1pt) A typing system which allows the type of a variable to change within a function is considered to have **Dynamic** typing.
G. (1pt) A language which only lets the programmers use a variable after they have declared it is considered to have _Explicit__ declaration.

H. (1pt) The `==` operator in Ruby and the `=` operator in OCaml are equivalent
   a) True  
   b) False

I. (1pt) The terms “closue” and “function pointer” have the same meaning
   a) True  
   b) False
2. Regular Expressions (10 pts)

   A. (3 pts) Write a Ruby regular expression for a password that must have at least 1 letter and at least 1 digit.

       /([a-zA-Z].*\d)|(^\d*[a-zA-Z])/  

   B. (2 pts) Give an example that adheres to the following regex:

       /^[a-zA-Z0-9.-]+@[a-zA-Z0-9.-]+\.[a-zA-Z]{2,5}$/

Valid email address

   C. (2 pts) Write the output of the following code:

       "HIST100 (about the past)" =~ /[A-Z]{4}(\d{3}) (.+)/

       puts $1
       puts $2

100
(about the past)

   D. (3 pts) Write the output of the following code: (Recall that foo.inspect gives the representation of foo as it would appear in source code, e.g. [1,2,3].inspect is "[1,2,3]".)

       s = "Computers need electricity."
       a = s.scan(/[a-z]+/)  

       puts a.inspect

["computers","need","electricity"]
3. **Ruby Execution (10 pts)**

Write the output of the following Ruby programs. If the program does not execute due to an error, write `NO OUTPUT` instead. Recall that `foo.inspect` gives the representation of `foo` as it would appear in source code, e.g., `[1,2,3].inspect` is `"[1,2,3]"`.

A. (4 pts)

```ruby
def myFun(x)
  yield x
end

myFun(3) { |v|
  str = v % 2 ? "foo" : "bar"
  puts "#{v} #{str}"
}
```

**Output:** `3 foo`


B. (3 pts)

```ruby
x = [5, 10]
x[3] = 20
y = x
y << ["a", "b"]
puts x.inspect
```

**Output:** `[5, 10, nil, 20, ['a', 'b']]`


C. (3 pts)

```ruby
foo = {1 => ['apple'], 2 => 'kiwi', 3 => 'yam'}
bar = foo.keys.sort { |a,b|
  foo[b].length <=> foo[a].length
}
puts bar.inspect
```

**Output:** `[2, 3, 1]`


A. (4 pts)

```ruby
def myFun(x)
  yield x
end

myFun(3) { |v|
  str = v % 2 ? "foo" : "bar"
  puts "#{v} #{str}"
}
```

**Output:** `3 foo`
4. Ruby Programming (15 pts)
You will be implementing a Ruby class named WordCounter which will read English text from a file and allow you to query the number of times a given word appears. For the purposes of this question, a word is a sequence of alphabetic characters. In our input files, words will be separated by whitespace and the following other characters: . , " : ;

You must implement the following methods. You may of course implement any other helper methods you wish. (5 points each):
- **initialize(flename)**: Reads the text from the file, extracts the words from the text, and stores them in an appropriate data structure. You may find it useful to use the IO.foreach method, which takes a filename and a code block, and passes each line in the file to the code block in turn, automatically closing the file when it reaches the end. Example usage:

  ```ruby
  IO.foreach("myfile.txt") { |line| puts line }
  ```
- **count(word)**: Returns the number of occurrences of word in the file. For the purposes of this question, words which differ by capitalization are considered separate words, e.g. “Cat” and “cat” would be considered separate words.
- **each**: Takes a code block and passes each word-and-count pair to it in turn. The order in which word-and-count pairs are passed to the block does not matter. You may assume that a code block will always be passed.

Example:

*had.txt:*
James had had "had," but John had had "had had."

**example usage:**
```
wc = WordCounter.new("had.txt")
puts wc.count("had")
wceach do |word, count|
  puts "#{word}: #{count}"
end
```

**output:**
```
7
James: 1
had: 7
but: 1
John: 1
```

**Solution:**
class WordCounter
  def initialize(filename)
    @word_counts = Hash.new(0)

    IO.foreach(filename) do |line|
      words = line.split(/\[\s.,:";]+/)  # Splitting the line into words
      words.each do |word|
        if word =~ /^[a-zA-Z]+$/  # Checking if the word is alphabetical
          @word_counts[word] += 1
        end
      end
    end

    def count(word)
      @word_counts[word]
    end

    def each
      @word_counts.each do |word, count|
        yield(word, count)
      end
    end
  end

Rubiic and partial ciedit options

Note: In the past students have implemented assignments like this with varying amounts of processing in the constructor. We have given 2 free points for the constructor assuming that most students won't check all of the validity constraints in the constructor, but instead in count and each. However, if the student checks all validity constraints in the constructor, the points for those constraints should be assessed on initialize and the free points given on count and each, to avoid double jeopardy.
5. OCaml Typing (16 pts)
Write Ocaml expression or definition of the following types without using type annotation:
A. (2 pts) (int * float) list

B. (3 pts) int -> string -> (int * string) list

C. (3 pts) 'a -> ('a -> bool) -> string

2. What is the type of the following expression?
A. (2 pts) ([1;2], “foo”)

B. (3 pts) let f x y = x::(y x 2)

C. (3 pts) let rec f x = match x with
| [] -> []
| h::t -> match h with
| (a,b) -> if (a = b) then a::(f t) else b::(f t);;

Solution:
1. Possible solutions:
   1. [(3, 3.14)]
   2. fun x y -> (x, y)::[(1, “hello”)]
   3. fun x f2 -> if (f2 x) then “hello” else “hello world”

2.
   1. int list * string
   2. 'a -> (int -> 'a -> 'a list) -> 'a list
   3. ('a * 'a) list -> 'a list
6. OCaml Execution (18 pts)

To the right of each code snippet, write what the variable res contains after executing the given code. Note that each code snippet contains syntactically and semantically valid OCaml code.

A. (3 pts)
let rec f x y = if y = 0 then x else f y (x mod y);;
let res = f 9 6;;

Output:3

B. (3 pts)
let a = ref "big";;
let b = ref "data";;
a := "buzz";;

let res = ((!a), (!b))

Output: ("buzz", "data")

C. (4 pts)
let proc f x y = if f x y > 0 then x else y;;
let res = proc (fun a b -> a * b) (-2) 4

Output:4

D. (4 pts)
let rec map f = function
| [] -> []
| x :: xs -> let z = f x in z :: map f xs
;;

let res =
let f x y = x := !x + (y * y); !x in
map (f (ref 0)) [1;2;3;4];;
Output: [1; 5; 14; 30]

4 pts

E. (4 pts)  (Hint: peivasive max of type \( \text{max} : 'a \to 'a \to 'a \) ietuins the gieatei of the two aiguments.)

\[
\text{type } \text{int\_tree} = \\
| \text{Leaf} \\
| \text{Node of int * int\_tree * int\_tree} \\
\]

let rec bar = function
| Leaf        -> -1
| Node(x, l, r) -> 1 + max (bar l) (bar r)

let res =
let t = (Node(1, Node(2, Leaf, Node(3, Leaf, Leaf)), Leaf)) in
bar t

Output: 2

4 pts

7. OCaml programming (18 pts)

A. (6 pts) Using fold and/or map, write a function \( \text{multi\_map} \) of type \( ('a -> 'a) -> ('a * int) \) list \( \to 'a \) list. This new higher order function applies the input function to each element of the input list however many times are specified by the second element of the tuple. Output oidei must be the same as the input oidei. If a negative int is encounteied, do not apply the function to that element.
Example input:
multi_map (fun x -> x * x) [(5, 1); (7, -1); (2, 3); (10, 2)]
> [25, 7, 256, 10000]

Solution:

let iec multi_map f xs =
  let iec helpei (n, i) = if i <= 0 then n else helpei (f n, i - 1)
  in map helpei xs

B. (6 pts) Using fold and/or map, write a function relative of type int list -> int list. This function decreases each element in the input list by the list's smallest integer.

Example input:
Relative [100; 80; 90]
> [20; 0; 10]

Solution:
let relative l = match l with
  | [] -> []
  | h :: t ->
    let s = fold min h t in
    map (fun h -> h - s) l

C. (6 pts) Using fold and/or map, write a function max_repeat of type 'a list -> int. This function finds the maximum number of times an element of the input list is repeated in a row. If the list is empty, the result should be 0.

Hint: The pervasive max might make your implementation easier.
val max : 'a -> 'a -> 'a
Return the greatest of the two arguments.

Example input:
max_repeat [1; 2; 2; 0; 3; 3; 3]
> 4

Solution:
let max_repeat = function
| [] -> 0
| h :: t ->
  let aux (c, n, m) h =
    if c = h then (c, n + 1, m)
    else (h, 1, max m n)
  in
  let (_, n, m) = fold aux (h, 1, 1) t in
  max n m