CMSC330 Spring 2017 Midterm #1
9:30am/11:00am/12:30pm/5:00pm

Name (PRINT YOUR NAME as it appears on gradescope):
__________________________________________________________________

Discussion Time (circle one) 10am  11am  12pm  1pm  2pm  3pm
Discussion TA (circle one)  Aaron   Alex   Austin   Ayman   Daniel   Eric
                                          Greg   Jake   JT   Sam   Tal   Tim   Vitung

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 (12 pts)

a) (3 pts) Which of the following statements are true of higher-order functions? Circle all that apply.
   i) They are functions that run in higher than O(n) time
   ii) They are functions that can return other functions
   iii) They are necessary for object-oriented programming
   iv) They are functions that receive other functions as arguments
   v) map and fold are examples of higher order functions

b) (3 pts) Show the contents of the closure for \( g \) after executing the following code
   \[
   \text{let } f = (\text{fun } x -> (\text{fun } y -> (\text{fun } z -> x * z)));;
   \]
   \[
   \text{let } g = f 10 20;;
   \]

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c) (6 pts) Circle T (true) or F (false) for the following statements (1pt each)
   i) T / F OCaml tuples are homogeneous.
   ii) T / F With immutable state, aliasing is irrelevant.
   iii) T / F Methods can be overloaded in Ruby.
   iv) T / F Ruby is a compiled language.
   v) T / F For OCaml, type inference happens at compile-time.
   vi) T / F Ruby has static typing.
2. Regular Expressions (12 pts)

a) (3 pts) Circle all of the strings that match the Ruby regular expression

/\d{3}.\d{4}$/

i) 732.7444
ii) 908-5490
iii) 201-901
iv) ddd.dddd

b) (3 pts) What is the output of the following Ruby code?

"Why was 6 afraid of 7?" =~ /\d\s(\w+).*(\d)/
puts $1
puts $2

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

s = "To be, or not to be!"
a = s.scan(/(\S+) (\S+)/)
puts a.inspect

d) (3 pts) A phone company needs to match serial numbers. The format is either 2 or 4
alphabetic characters followed by 1 to 3 numeric characters. Write the a Ruby regular
expression which matches these serial numbers.

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<td>aT7</td>
<td>76n</td>
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<tr>
<td>op115</td>
<td>k997</td>
</tr>
<tr>
<td>uaqt345</td>
<td>abcde123</td>
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3. Ruby Execution (10 pts)

Write the output of the following Ruby code. If there is an error, then write FAIL.

a) (3 pts)

```ruby
arr = [true, nil, false, 0]  
output:
arr.each do |x|
  if x then
    puts “Ruby”
  else
    puts “Crystal”
  end
end
```

b) (4 pts)

```ruby
class JellyBean
  def initialize
    @@flavors = ["blue", "red", "purple", "yellow"]
  end
  def foo(f)
    @@flavors.push f
  end
  def flavors
    @@flavors
  end
end
j = JellyBean.new()
k = JellyBean.new()
j.foo("orange")
k.foo("rainbow")
puts j.flavors.inspect
```

c) (3 pts)

```ruby
h = { "a"=>4, "b"=>3, "c"=>2, "d"=>1 }
r = h.values.select { |x| x % 2 == 0 }
r.sort!
puts r.inspect
```
4. Ruby Programming (18 pts)

For this question, you implement a "memory game" in class MemoryGame. In the game, a player picks two cards (each an object of class Card) from a deck (an object of class Deck). If the two cards have the same face value (regardless of suit), they are marked as matched. Players may not match cards that have been matched previously. Players can play until every card is matched. We provide starter code for the Card and Deck classes below. Notice that:

- Suits are strings: "Spades", "Clubs", "Hearts", "Diamonds"
- Values are strings or integers: "Ace", "King", "Queen", "Jack", 2, 3, 4, 5, 6, 7, 8, 9, 10
- The deck is shuffled when it is created.

class Card
  attr_accessor :suit, :value
  def initialize(s, v)
    @suit = s
    @value = v
  end
  ...
  # you will add a method here
end

class Deck
  def initialize
    @cards = []
    suits = ["Spades", "Clubs", "Hearts", "Diamonds"]
    values = ["Ace", "King", "Queen", "Jack", 2, 3, 4, 5, 6, 7, 8, 9, 10]
    values.each do |v|
      suits.each do |s|
        c = Card.new(s,v)
        @cards.push(c)
      end
    end
    @cards.shuffle!  # randomly permutes the cards
  end
  ...
  # you will add two methods here
end
a) (6 pts) Write the `self.from_string(s)` static method for the `Card` class. This method receives a string in “value suit” format (for example: “10 Clubs”, “Queen Spades”), and creates a card with that value and suit. It returns `nil` if the given string is not a valid value and suit.

```ruby
def self.from_string(s)
    # end of self.from_string method
end
# end of Card class
```

b) (2 pts) Write the method `cardAt(n)` for the `Deck` class. It returns the card at position `n` (where indexing starts at 0). Returns `nil` if there is no card at that position.

```ruby
def cardAt(n)
    # end of Deck’s cardAt method
end
```

c) (2 pts) Write the method `numCards` for the `Deck` class, which returns the number of cards in the deck.

```ruby
def numCards
    # end of Deck’s numCards method
end
# end of Deck class
```
d) (8 pts) Write the MemoryGame class, which implements the “memory game” described above. The MemoryGame constructor creates a fresh Deck and stores it in field @d. You must implement method `match(n1,n2)`, which checks if two cards at positions n1 and n2 in Deck @d have the same values (irrespective of the suit). You may need to add code to the constructor.

`match(n1,n2)` returns true if
- the cards at positions n1 and n2 in Deck @d have the same value and
- have not been matched before (i.e., `match(n1,n2)` has not previously returned true)

`match(n1,n2)` returns false if
- n1 == n2, or
- n1 or n2 are not valid positions in the Deck @d, or
- the cards at n1 and n2 do not have the same value, or
- the cards at n1 and n2 were part of a previous match

```ruby
class MemoryGame
  def initialize  # hint: add a data structure to keep track of matched cards
    @d = Deck.new
  end  # end of initialize

  def match(n1,n2)
    # code to implement the match method
  end  # end of match method
end  # end of MatchGame class
```
5. OCaml Typing (12 pts)

a) Determine the types of the following OCaml expressions

1. (2 pts) [(1, 3.14, “hello”)]

2. (2 pts) fun a b c -> if a then (b a) else (c a)

3. (2 pts) let f x m =
    match m with
    | [] -> x
    | h::_ -> x + h

b) Provide an OCaml expression that has the given type. (You may not use type annotations.)

1. (3 pts) int -> int list -> int list

2. (3 pts) `a * `b -> (`b -> `a) -> `a list
6. OCaml Execution (18 pts)

Write **what the following expressions evaluate to.** If there is an error, write ERROR and circle the error in the code. Below are implementations of map and fold below for reference (they are equivalent to the standard List.map and List.fold_left functions).

```ocaml
let rec fold f a l =  
  match l with  
  | [] -> a  
  | h::t -> fold f (f a h) t  
;;

let rec map f l =  
  match l with  
  | [] -> []  
  | h::t -> let r = f h in r::(map f t)  
;;
```

a) (3 pts.) let cmsc f x y = if (f x y = 0) then 1 else 0 in  
            cmsc (fun a b -> a - b) 4 4

b) (3 pts.) map (fun x -> x + 2) (6::[1;4;5])

c) (4 pts.) let f l = fold (fun a x -> a || x) false l in  
           if f [false; true; false] then 1 else 0
d) (4 pts.)

\[
\begin{align*}
\text{let } x &= 7 \text{ in} \\
\text{let } \text{add } a\ b &= a + b \text{ in} \\
\text{let } \text{addto } &= \text{add } x \text{ in} \\
\text{let } x &= 40 \text{ in} \\
(\text{addto } 10, \text{add } x\ 10, \text{addto } x)
\end{align*}
\]

e) (4 pts.)

\[
\begin{align*}
\text{let } f &= \\
\text{let } c &= \text{ref } 0 \text{ in} \\
\text{fun } x -> c := !c + x; !c \text{ in} \\
(f\ 2) + (f\ 4)
\end{align*}
\]

7. OCaml Programming (18 pts)

Implement the following functions. You are allowed to add helper functions for any of these problems if you like.

a) (6 points) Define a function \texttt{repeat : int * `a -> `a list} that takes a non-negative integer \(n\) and a value \(x\) and returns a list containing \(n\) copies of \(x\). (You may implement this with \texttt{fold} or \texttt{map}, if you wish.) Examples:

\texttt{repeat (0,1) = []; repeat (2,"hello") = ["hello"; "hello"];}

b) (6 points) Define a function \texttt{unpack l : (int * `a) list -> `a list} that takes a list of of pairs and returns a list of the second elements of those pairs, where those elements appear as many times as indicated by the first elements. This is called “run length” format.

(cont’d next page)
You may not write a recursive function; instead you must use fold and/or map (whose definitions are given in problem 6, above). If you wish, you may use any function in the List or Pervasives library, or anywhere else in this exam, to help.

unpack [(1,2);(3,1);(2,5)] = [2;1;1;1;5;5];
unpack [(2,"hello");(0,"fourteen")]] = ["hello";"hello"];

c) (6 points) Consider the following variant type definition exp, which represents arithmetic expressions that involve integer constants, multiplication, and addition:

```
type exp =
  | Int of int
  | Mult of exp * exp
  | Plus of exp * exp
```

Define a function eval : exp -> int that takes an expression and returns the int it evaluates to. Examples:

```
eval (Int 3) = 3;;
eval (Plus(Int 1,Int 2)) = 3;;
eval (Mult(Plus(Int 1,Int 2),Int 3)) = 9;;
eval (Mult(Int 2,Plus(Int 1,Int 2))) = 6;;
```