Final Exam
CS 1101 Computer Science I
Spring 2016

Section 03

KEY

Tuesday May 10, 2016

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Before reading further, please arrange to have an empty seat on either side of you. Now that you are seated, please write your name **on the back** of this exam.

This is a closed-notes and closed-book exam. Computers, calculators, and books are prohibited.

This is a 29 point exam.

- Partial credit will be given so be sure to show your work.
- Feel free to write helper functions if you need them.
- **Please write neatly.**

Problem	Points	Out Of
1		**11**
2		**12**
3		**6**
Total		**29**

Section 1 (11 Points Total)

1. (1 Point) In a sentence or two, what does the word *scope* mean with respect to a piece of code?

   Answer: Scope refers to the region of text where a bound symbol can be meaningfully referenced.

2. (1 Point) In a sentence or two, what does the phrase *abstract data type* mean?

   Answer: An abstract data type is a methodology for introducing new types. It emphasizes the separation of the *specification* of the new type from the *implementation* of the new type.

3. (1 Point) Is the following well-defined? If so, what is its value?

```
let f = List.map (fun x -> "BC")
in
f [false; true]
```

Answer: Yes it is well typed with value `["BC"; "BC"]`.

4. (1 Point) $567_8 = X_2$. Solve for X.

Answer: X = 101110111.

5. (1 Point) $16_{16} + 16_8 = X_{10}$. Solve for X.

Answer: $X = 36$**.**

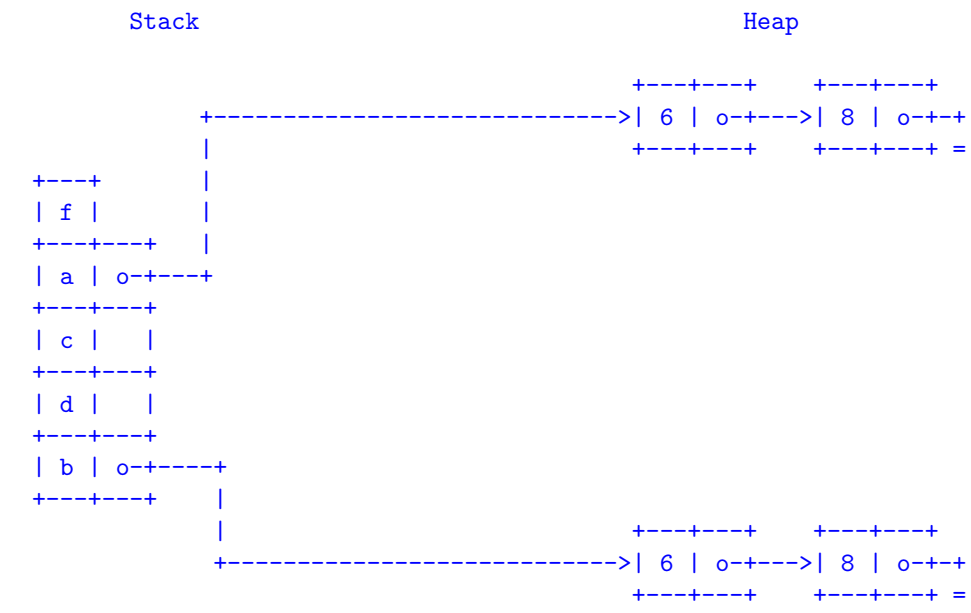
6. (2 Points) Consider the following definition.

```
let f a =
  let b = [6; 8] in                                (1)
  let c = a in                                     (2)
  let d = [(1, c); (3, c); (3, c)]                 (3)
  in
  d                                                (4)

f [6; 8]
```

Show the state of the stack and the heap after (1) has executed but before (2) has executed.

Answer:



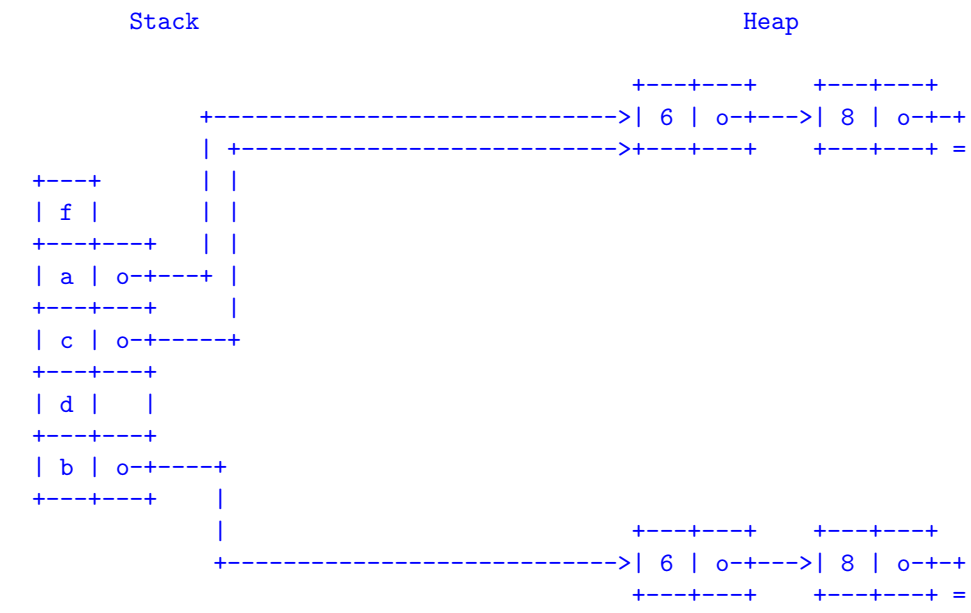
7. (2 Points) Consider the same definition.

```
let f a =
  let b = [6; 8] in                                (1)
  let c = a in                                     (2)
  let d = [(1, c); (3, c); (3, c)]                 (3)
  in
  d                                                (4)

f [6; 8]
```

Show the state of the stack and the heap after (2) has executed but before (3) has executed.

Answer:



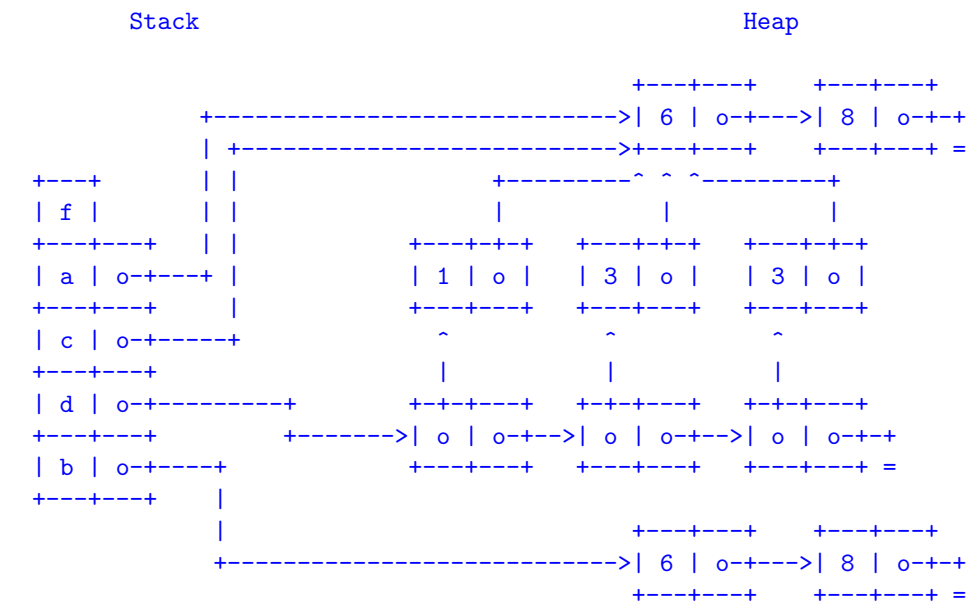
8. (2 Points) Consider the same definition.

```
let f a =
  let b = [6; 8] in                                (1)
  let c = a in                                     (2)
  let d = [(1, c); (3, c); (3, c)]                 (3)
  in
  d                                                (4)

f [6; 8]
```

Show the state of the stack and the heap after (3) has executed but before (4) has executed.

Answer:



Section 2 (12 Points Total)

1. (2 Points) Python has a handy feature for grabbing a slice of a list. For example, if `xs` is the list `[2, 4, 6, 8]` the Python notation `xs[1:3]` denotes the sublist `[4, 6]`. I.e., the elements from position `1` up to but not including position `3`.

   Write an OCaml function `slice : 'a list -> int -> int -> 'a list` such that a call of the function `(slice xs lo hi)` behaves like the Python slicer. You may assume that both `lo` and `hi` are non-negative, that `lo < hi` and that `hi <= List.length xs`.

   Answer:

```
let rec slice xs lo hi =
  match lo = hi with
  | true  -> []
  | false -> (List.nth xs lo) :: slice xs (lo + 1) hi
```

2. (2 Points) Write the function `slice : 'a array -> int -> int -> 'a array` which behaves like the above described function but with an array input rather than a list. In solving this you can make the same assumptions as above and you may use `Array.make : int -> 'a -> 'a array` but you may not use the `Array.to_list` function.

   Answer:

```
let slice a lo hi =
  let b = Array.make (hi - lo) a.(lo)
  in
  for i = 0 to (hi - lo - 1) do
    b.(i) <- a.(lo + i)
  done;
  b
```

3. (4 Points) Write a function `median : int list -> int` such that a given call `(median ns)` returns the *median* of `ns`. That is, the number `n` from `ns` such that there are an equal number of numbers in `ns` that are smaller than `n` as larger than `n`. For example, the call `(median [8; 5; 2; 6; 3])` should return `5` because there are 2 numbers smaller than 5 and 2 numbers larger than 5. You may assume that there will be a unique median. If you solve this problem by sorting, write a complete implementation of a `sort` function.

Answer:

```
let rec count n ns =
  match ns with
  | [] -> (0, n, 0)
  | m :: ms -> let (smaller, _, larger) = count n ms
               in
               match compare m n with
               | -1 -> (1 + smaller, n, larger)
               |  0 -> (smaller, n, larger)
               |  1 -> (smaller, n, 1 + larger)

let rec findMiddle triples =
  match triples with
  | [] -> failwith "not going to happen"
  | (smaller, n, larger)::rest -> (match smaller = larger with
                                   | true  -> n
                                   | false -> findMiddle rest)

let median ns =
  let counts = List.map (fun n -> count n ns) ns
  in
  findMiddle counts
```

4. (4 Points) Lets say a list has unwanted consecutive duplicates. For example, `[1; 2; 2; 2; 3; 3]` rather than `[1; 2; 3]`. Write the function `remDups : 'a list -> 'a list` which repairs such a list by removing consecutive duplicates.

Answer:

```
let rec remDups xs =
  match xs with
  | [] -> []
  | _ :: [] -> xs
  | x :: y :: ys -> let almost = remDups (y :: ys)
                    in
                    (match x = y with
                     | true  -> remDups almost
                     | false -> x :: remDups almost)
```

Section 3 (6 Points Total)

(6 Points) Consider a function `counts : 'a list -> ('a * int) list`. A call `(counts xs)` should evaluate to a list containing the elements of `xs` paired up with the number of occurrences in `xs`. For example, `(counts ['A'; 'B'; 'A'; 'A'])` should return the list `[('A', 3); ('B', 1); ('A', 3); ('A', 3)]`. **Write two versions of the `counts` function. The two versions should use different repetition idioms.**

Answer:

```
let rec count x xs =
  match xs with
  | [] -> 0
  | y :: ys -> (match x = y with
                | true  -> 1 + (count x ys)
                | false -> count x ys)

let counts xs =
  let ns = List.map (fun x -> count x xs) xs
  in
  List.combine xs ns

let counts xs =
  let rec repeat ys =
    match ys with
    | [] -> []
    | y :: ys  -> (y, count y xs) :: repeat ys
  in
  repeat xs
```