CMSC330 Spring 2010 Midterm #2

Name ______________________________________

Discussion Time (circle one): 9am 10am 11am 12pm 1pm 2pm

Do not start this exam until you are told to do so!

Instructions

- 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.
- If you have a question, please raise your hand and wait for the instructor.
- Answer essay questions concisely using 2-3 sentences. Longer answers are not necessary and a penalty may be applied.
- In order to be eligible for partial credit, show all of your work and clearly indicate your answers.
- Write neatly. Credit cannot be given for illegible answers.

	Problem	Score
1	OCaml types & type Inference	/16
2	Higher order & anonymous functions	/14
3	OCaml polymorphic datatypes	/16
4	Context free grammars	/16
5	Parsing	/22
6	Operational semantics	/16
	Total	/100

1. (16 pts) OCaml Types and Type Inference

   Give the type of the following OCaml expression

   a. (2 pts) [[1 ; 2]] **Type =**

   b. (3 pts) fun x -> 2::x **Type =**

   Write an OCaml expression with the following type

   c. (2 pts) int list -> int **Code =**

   d. (4 pts) (int -> bool) -> int **Code =**

   Give the value of the following OCaml expression. If an error exists, describe it

   e. (2 pts) if (1 < 2) then 3 **Value / Error =**

   f. (3 pts) let f x = f 2 in 1 **Value / Error =**

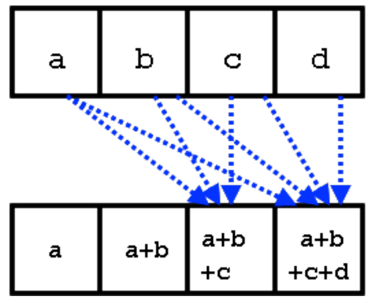
```
let rec fold f a lst = match lst with
    [] -> a
   | (h::t) -> fold f (f a h) t
```

2. (14 pts) Higher order & anonymous functions

A *prefix sum* is an operation on lists in which the n^{th} element in the result list is obtained from the sum of the first *n* elements in the operand list. Using the following code for fold and an anonymous function, write a function prefixSum which given a list of ints, returns the prefix sum for the list.

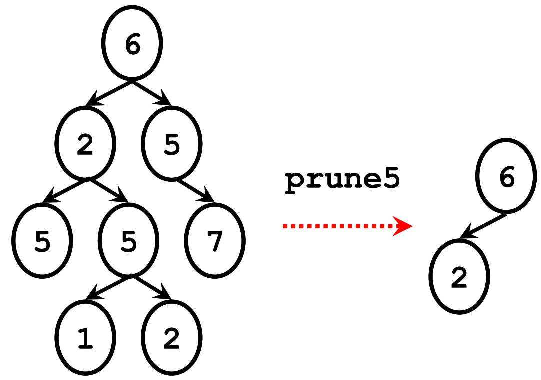
You are not allowed to use any helper functions or OCaml library functions, with the exception of List.rev (which reverses a list).

Partial credit given for solutions which do not use fold.



Example: prefixSum [ ] = [ ]
prefixSum [1;1;1;1;1] = [1;2;3;4;5]
prefixSum [1;2;3;4] = [1;3;6;10]

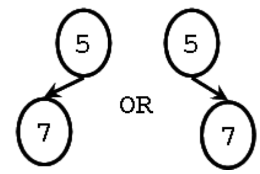
3. (16 pts) OCaml polymorphic datatypes



Consider the OCaml type *tree* implementing a binary tree of ints:

```
type tree =
   Empty
   | Node of int * tree * tree;;
```

a. (4 pts) Write an OCaml expression creating the data structure for a binary tree where the root node has value 5 and has one child node with value 7.



b. (5 pts) Implement a function *count5* that takes a tree and returns the number of nodes with the value 5. You may use helper functions (though they are not needed).

c. (7 pts) Implement a function *prune5* that takes a tree and returns a tree where all nodes with the value 5 (and their subtrees) are removed. You may use helper functions (though they are not needed).

4. (16 pts) Context free grammars
   Consider the following grammar: $S \rightarrow S\ x\ T \mid T \qquad T \rightarrow a \mid b$

   a. (3 pts) Describe the set of strings generated by the grammar

   b. (3 pts) Provide a left-most derivation for the string “axbxb”.

   c. (2 pts) Provide a parse tree for the string “axbxb”.

   d. (2 pts) What is the associativity of the x operator for the grammar?

   e. (6 pts) Apply the algorithm discussed in class to transform the grammar so that it can be parsed using a recursive descent parser.

5. (22 pts) Parsing semantics **(This question is irrelevant. We did not cover parsing in this semester)**

Consider the following grammar

$S \rightarrow Abc \mid dS \mid \varepsilon$ (* epsilon *)

$A \rightarrow aSA \mid f$

a. (8 pts) Compute First sets for S and A

b. (14 pts) Using pseudocode, write a recursive descent parser for the grammar.

Use the following utilities:

lookahead	Variable holding next terminal Lookahead == "$" when at end of input
match (x)	Function to match next terminal to x
error ( )	Reports parse error for input

6. (16 pts) Operational semantics **(This question is irrelevant. We did not cover operational semantics in this semester)**

a. (4 pts) Consider the following operational semantics judgement. State in English what this statement is expressing:

$\bullet$, x:1 ; (+ x 2) $\rightarrow$ 3

b. (12 pts) In an empty environment, to what value v will the expression

(fun z = z) (+ 1 2)

evaluate to? In other words, find a v such that you can prove the following:

$\bullet$; (fun z = z) (+ 1 2) $\rightarrow$ v

Use the operational semantics rules given in class. Show the complete proof that stacks uses of these rules.