

## Midterm Examination

Your **full** name:

UCSD id number:

You may bring and use the following materials: your own personal hand-written notes, and a printed copy of the published lecture and section notes. You may not use any books or any other materials.

Look through the whole exam and answer the questions that you find easiest first. Write your answers below each question, using the backs of the pages if necessary.

Whenever you make an assumption, state it clearly. Whenever you are asked to give example code in a certain programming language, you are not required to get the syntax exactly right, but your code should be recognizable and understandable, with the most important language keywords used appropriately.

**(Question 1)** [10 points] A two-dimensional array can be represented in ML as a list of lists. For example, a 3 by 3 array of integers can be represented as [ [1,2,3], [4,5,6], [7,8,9] ].

(a) [5 points] Write a recursive ML function that finds the maximum value in a two-dimensional array of integers represented in this way.

(b) [5 points] Now we want to generalize the function from part (a) to find the *last* component of the array that satisfies a given Boolean function. This function is higher-order, and should have signature

```
(int -> bool) -> (int list) list -> int.
```

Give simple code for this ML function.

- (Question 2)** [20 points] (a) [5 points] Both C and ML allow union types. Use short examples to show how to implement a union type in each language.
- (b) [5 points] Why is it more accurate to call union types *disjoint* union types? Is disjointness enforced in C? In ML? Explain your answers briefly.
- (c) [5 points] Both C and ML have types to represent data structures implemented with pointers, such as trees. However there are major differences. Explain these differences briefly.
- (d) [5 points] Personally, do you prefer the C type system, or the ML type system? Give two good reasons for your answer. (We will grade your answer based on how good your reasons are. You are free to prefer C or ML.)

**(Question 3)** [10 points] (a) [5 points] Using an example, explain carefully what dynamic binding is in object-oriented programming.

(b) [5 points] Give a short high-level explanation of an example of a real-world programming task where a well-designed object-oriented program would use inheritance and dynamic binding.