5 Concepts in Programming Languages (AM)

(a) Explain what is meant by a monad in a programming language, giving the two fundamental operations of a monad along with their types. [3 marks]

(b) Consider the use of a monad for input-output. For the purposes of this question, take the IO monad as including two operations `readint` and `writeint` which respectively read integers from stdin and write integers to stdout. Give the types of these operators. [2 marks]

(c) Assume `MLreadint` and `MLwriteint` are primitives with side effects for input-output and consider the ML expression `add1` of type `int`:

\[ \text{let val x = MLreadint() in MLwriteint(x+1); x end} \]

(i) Give an equivalent expression which uses the IO monad instead of side-effects, and state its type. [3 marks]

(ii) Give a function `run2diff` which can be applied to your answer to part (c)(i). When so applied it should give a value in the IO monad which corresponds to ML code that runs `add1` twice and returns the difference between the values read. [4 marks]

(d) State what happens when attempting to compile and execute the following Java fragment (explaining the origin of any error messages or exceptions which might arise).

Object n = new Integer(42), o = new String("Whoops");
Object [] v;
Integer [] w = new Integer[10];
v = w;
v[4] = n;
v[5] = o; [4 marks]

(e) Consider the Java code:

Object n = new Integer(42);
ArrayList<? extends Object> v1;
ArrayList<Object> v2;
ArrayList<Integer> w = new ArrayList<>(10);

Explain any differences in behaviour between assignments v1 = w and v2 = w and also between method calls v1.set(4,n) and v2.set(4,n). [4 marks]