

COMPUTER SCIENCE TRIPOS Part IB – 2016 – Paper 3

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`:

```
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]