

# 1993 Paper 12 Question 9

## Introduction to Functional Programming

Consider the ML definitions

```
fun N f x = x;  
fun P a k f x = f a (k f x);  
fun Q k l f x = k f (l f x);  
fun W a k = Q k (P a N);  
fun R k = k W N;
```

Suppose further that  $K$  and  $L$  have ML definitions of the form

```
val K = P a1 (P a2 ... (P ai N) ...);  
val L = P b1 (P b2 ... (P bj N) ...);
```

In parts (b) to (d) below, assume that  $f$  and  $x$  are arbitrary ML identifiers of suitable type for the expression containing them.

- (a) State the ML types of  $N$  and  $P$ . [3 marks]
- (b) What does the expression  $K f x$  evaluate to? [3 marks]
- (c) What does the expression  $Q K L f x$  evaluate to? [4 marks]
- (d) What does the expression  $R K f x$  evaluate to? [10 marks]