Twenty-part question (One mark per part)

(a) Give some ML text to replace <insert> in the following:

<insert>
fun f g g = g; f x y;

to make it into a valid ML program.

(b) Given the following ML function definition:

fun h x y z = x (y z);

what is the type of h?

(c) Let A be the set \{1, 2, 3, 4\}. Exhibit (or state briefly why this is impossible) a relation R on A which is a function whose inverse relation R\(^{-1}\) is a partial function, but not a (total) function.

(d) Solve the recurrence

\[
\begin{align*}
  f(0) &= 0 \\
  f(1) &= 3 \\
  f(n + 2) &= 6f(n + 1) - 9f(n)
\end{align*}
\]
(e) It is claimed that there is a bijection from \((A+B) \to C\) to \((A \to C) \times (B \to C)\). Demonstrate this by replacing both “...” below with valid ML code which might form such a bijection and its inverse. Just ML is required, not proof.

```ml
datatype BplusS = left of bool | right of string;
fun LtoR(f: BplusS -> real)
  : (bool->real) * (string->real)
  = ...;
fun RtoL((g: bool->real), (h: string->real))
  : (BplusS -> real)
  = ...;
```

(f) Give an equation involving a set named \(S\), such that the smallest (with respect to \(\subseteq\)) solution for \(S\) is the set of values represented by the ML datatype \(s\):

```ml
datatype s = empty | leaf of int | branch of s*s;
```

Your solution may reasonably involve the constructors \(\text{empty}\), \(\text{leaf}\) and \(\text{branch}\).

(g) Given an integer value between 0 and 9, show an expression in Modula-3 for the equivalent character.

(h) What output would the following Modula-3 fragment produce when \(P\) was called?

```modula
PROCEDURE P () =
  PROCEDURE Q (VAR a: INTEGER) =
    BEGIN a := 2 * a + b END Q;
  VAR a := 1; b := 2; c := 3;
  BEGIN
    Q (c);
    IO.Put (Fmt.Int (a) & "\n");
    IO.Put (Fmt.Int (b) & "\n");
    IO.Put (Fmt.Int (c) & "\n");
  END P;
```

(i) What is meant by an address space?

(j) How are operating system services invoked?
(k) What is this?

(l) What is the minimum sum of product form for the function specified by the following map in which X indicates don’t care?

(m) Identify at least one other factor involved in computer security beyond technical measures such as provision of password access.

(n) Name two branches of the law under which software ownership can be protected.

(o) Provide a generating function $G(\eta)$ that is suitable for a random variable which is distributed Geometric($p$).

(p) Given that $P(X=0) = P(Y=0) = \frac{1}{4}$ and that $P(X=0 \cap Y=0) = \frac{1}{8}$, determine $P(X \neq 0 \cap Y \neq 0)$.

(q) Describe the way in which Regular Expressions are constructed.

(r) How does the minimum time in which a large software project can be completed depend on the number of staff allocated to it?
(s) Give in binary a pair of five-bit numbers which when added give the correct result when considered as unsigned integers but which overflow when considered as two's complement numbers.

(t) What is meant by top–down programming and how does it differ from bottom–up programming?