10 Semantics of Programming Languages (nk480)

Consider the language with functions, integers, and printing.

$$\begin{array}{lcll} \tau & ::= & \mathsf{unit} \mid \mathsf{int} \mid \tau \to \tau' & \text{Types} \\ e & ::= & x \mid \lambda x : \tau.\, e \mid e\, e' \mid \mathsf{skip} \mid n \mid \mathsf{print}(e) \mid e; e' & \text{Terms} \end{array}$$

The typing rule for $\mathsf{print}(e)$ is:

$$\frac{\Gamma \vdash e : \mathsf{int}}{\Gamma \vdash \mathsf{print}(e) : \mathsf{unit}}$$

(*a*) Define a small-step, call-by-value operational semantics for this language. Clearly explain what the components of the machine configuration are, and how it identifies what is printed. [10 marks]

(*b*) State a progress theorem for this language, and explain what it says about the evolution of the machine state. [4 marks]

(*c*) Prove progress for the $\mathsf{print}(e)$ case, giving the names of any of the standard properties (such as substitution) that you needed to use in the proof. [6 marks]