

10 Semantics of Programming Languages (nk480)

Consider the language with functions, integers, and printing.

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

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

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

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