9 Semantics of Programming Languages (PMS)

Consider the following language syntax:

Booleans \( b \in B = \{ \text{true}, \text{false} \} \)
Natural numbers \( n \in N = \{ 0, 1, \ldots \} \)
Locations \( \ell \in L = \{ l, l_0, l_1, l_2, \ldots \} \)
Operations \( op ::= + | - | \geq \)

Expressions

\[
e ::= n \mid b \mid e_1 \ op \ e_2 \mid \text{if } e_1 \ \text{then } e_2 \mid \ell := e \mid \text{skip} \mid e_1 ; e_2 \mid \text{print } e
\]

Types \( T ::= \text{nat} \mid \text{bool} \mid \text{unit} \mid T \text{ref} \)

(a) Define a reasonable operational semantics and type system for this syntax. Your
operational semantics should be expressed as a relation

\[
\langle e, s \rangle \xrightarrow{L} \langle e', s' \rangle
\]

where \( s \) models the store and the label \( L \) is either \( n \) (for a print of that natural number) or \( \tau \) (for an internal transition). Your type system should be expressed as a relation

\[
\Gamma \vdash e : T
\]

Make clear what \( s \) and \( \Gamma \) range over in your semantics.

[12 marks]

(b) Explain the main design choices you made in part (a), giving alternative rules or
examples (of expressions, transitions, or derivations of transitions or typing) as
appropriate. Discuss whether your semantics has type preservation and progress
properties.

[8 marks]