

Side-effect: anything which affects a program's execution, result, or environment which is not the program itself

* System state

* User input

* Randomization *

$$\frac{v \in \mathbb{Z}}{\text{RandomInt} \Rightarrow v}$$

FbS — S = State

$e ::= \dots \mid \text{Ref } e \mid e := e \mid !e$

$v ::= \dots \mid c$

$c ::=$ (infinite set of cell names)
no concrete syntax

$S ::= \{ c \mapsto v, \dots \}$
where c is unique

Fb, FbR, FbV, FbP, ... : $e \Rightarrow v$

FbS : $\langle S, e \rangle \Rightarrow \langle S, v \rangle$

Ref Rule $\frac{\langle S, e \rangle \Rightarrow \langle S', v \rangle \quad c \notin S' \quad S' \{ c \mapsto v \} = S''}{\langle S, \text{Ref } e \rangle \Rightarrow \langle S'', c \rangle}$

Assignment Rule $\frac{\langle S, e_1 \rangle \Rightarrow \langle S', c \rangle \quad \langle S', e_2 \rangle \Rightarrow \langle S'', v \rangle \quad S'' = (S' \setminus \{ c \mapsto v \}) \cup \{ c \mapsto v \} \quad c \mapsto v \in S''}{\langle S, e_1 := e_2 \rangle \Rightarrow \langle S'', v \rangle}$

Dereference Rule $\frac{\langle S, e \rangle \Rightarrow \langle S', c \rangle \quad (c \mapsto v) \in S'}{\langle S, !e \rangle \Rightarrow \langle S', v \rangle}$

(Ref 0) := 4

$x \in (y = (z = 0))$

Value Rule $\frac{}{\langle S, v \rangle \Rightarrow \langle S, v \rangle}$

Plus Rule $\frac{\langle S, e_1 \rangle \Rightarrow \langle S', v_1 \rangle \quad \langle S', e_2 \rangle \Rightarrow \langle S'', v_2 \rangle}{\langle S, e_1 + e_2 \rangle \Rightarrow \langle S'', v \rangle}$ v is the integer addition of v_1 and v_2