

# Language Syntax, Semantics, Runtime Errors

CS 536: Science of Programming, Fall 2022

Due **Wed Sep 21**, Not Tue Sep 20, 11:59 pm

2022-09-21, 14:59: Restored problems 4 – 6. 2022-09-22, 14:37 Typo in #6

## Problems [60 points]

### Class 5: Language Syntax/Operational Semantics

1. [12 = 4 \* 3 points] Translate the program below into our programming language.
  - a. `m = x = 0; y = 1; while (m++ < n) { ++x; y *= x ; }`
  - b. `m = n; x = z = 1; while (--m < n) { x++; x += z ; }`
  - c. `m = n; v = x = 1; while (--m < n) { x++; v += x ; }`
  - d. `m = n; p = y = 1; while (--m < n) { ++p; p += y ; p++; p += z; }`

For Problems 2 and 3, write out the operational semantics as a directed graph. (With  $\langle S, \sigma \rangle \rightarrow \langle S', \sigma' \rangle$ , the two configurations become nodes and the semantics  $\rightarrow$  becomes a graph  $\rightarrow$ .) For these problems, it's okay to draw your answers on paper and scan it in to be part of your pdf. If the same configuration occurs more than once, don't write it out as two separate nodes; make it just one node.

2. [12 = 3 \* 4 points] Let  $S \equiv \text{if } x > 0 \text{ then } x := x * z \text{ else if } y > 0 \text{ then } y := y * z \text{ fi fi}$ .
  - a. Evaluate  $\langle S, \{x = 3, y = 5, z = 9\} \rangle$  to completion.
  - b. Evaluate  $\langle S, \{x = -2, y = 4, z = 3\} \rangle$  to completion.
  - c. Evaluate  $\langle S, \{x = -5, y = -2, z = -2\} \rangle$  to completion.
3. [9 points] Let  $W \equiv \text{while } m \neq n \text{ do } S \text{ od}$  where  $S \equiv m := m + 1; x := x + m * m$ . Let  $\sigma_0 = \{m = 0, x = 1, n = 4\}$ . Evaluate  $\langle W, \sigma_0 \rangle$  to completion. Show all configurations of the form  $\langle W, \text{state} \rangle$  and the final  $\langle E, \text{state} \rangle$ . You can use  $\rightarrow^n$  to skip other configurations if you like, or you can show them (your choice).

### Class 6: Denotational Semantics, Runtime Errs [2022-09-21 restored]

4. [9 = 3 \* 3 points] As in problem 2, let  $IF \equiv \text{if } x > 0 \text{ then } x := x * z \text{ else if } y > 0 \text{ then } y := y * z \text{ fi fi}$ .
  - a. What is  $M(IF, \{x = 3, y = 5, z = 9\})$ ?
  - b. What is  $M(IF, \{x = -2, y = 4, z = 3\})$ ?
  - c. What is  $M(IF, \{x = -5, y = -2, z = -2\})$ ?

5. [10 points] As in Problem 3, let  $S \equiv m := m+1; x := x+m*m$  and let  $W \equiv \text{while } m \neq n \text{ do } S \text{ od}$ .
- [3 points] Let  $\tau$  be an arbitrary state for  $S$ . What is  $M(S, \tau)$ ? (Your answer will be symbolic.)
  - [3 points] Let  $\sigma_0 = \{m = 0, x = 0\}$ . What values of  $\beta \in \mathbb{Z}$  make  $M(W, \sigma_0[n \mapsto \beta]) = \perp_d$ ?
  - [4 points] For the other values of  $\beta$ , write a simple description of the value of  $\delta$  in

$$M(W, \sigma_0[n \mapsto \beta]) = \{\{m = \beta, x = \delta, n = \beta\}\}$$

Something at the level of “ $\delta$  is the sum of all the odd integers between 1 and  $\beta$ ” is fine.

(Except that it's a wrong answer, of course.)

6. [8 points] Let  $S \equiv x := b[m+1] / \text{sqrt}(k)$  and let  $\sigma = \{m = \alpha, k = \beta, b = \gamma\}$ . Let  $\delta$  be the length of  $b$ , so [2022-09-22]  $\gamma(0), \dots, \gamma(\delta-1)$  are the values of  $b[0], b[1], \dots$  in  $\sigma$ . Describe the set of all  $\sigma$  that cause  $M(S, \sigma) = \{\perp_e\}$ . Recall dividing by zero and taking square roots of negative numbers cause errors.