# CO240 - Models of Computation **Tutorial Sheets**

## Tutorial 1 - Expressions

1. d Consider the **big-step** operational semantics for the language *SimpleExp* given in the lectures. Find a number $n$ such that

$$(4+1)+(2+2) \Downarrow n$$

Give the full derivation tree.

$$\text{(B-ADD)}\ \dfrac{\text{(B-ADD)}\ \dfrac{\text{(B-NUM)}\ \dfrac{}{4 \Downarrow 4} \qquad \text{(B-NUM)}\ \dfrac{}{1 \Downarrow 1}}{(4+1) \Downarrow 5} \qquad \text{(B-ADD)}\ \dfrac{\text{(B-NUM)}\ \dfrac{}{2 \Downarrow 2} \qquad \text{(B-NUM)}\ \dfrac{}{2 \Downarrow 2}}{(2+2) \Downarrow 2}}{(4+1)+(2+2) \Downarrow 9}$$

2. The big-step operation semantics for *SimpleExp* was only given for addition. Extend it to include *multiplication*. Give a proof that $((3+2) \times (1+4)) \Downarrow 25$

To do this, we need to add an additional rule as follows;

$$\text{(B-MUL)}\ \dfrac{E_1 \Downarrow n_1 \qquad E_2 \Downarrow n_2}{E_1 \times E_2 \Downarrow n_3}\ n_3 = n_1 \times n_2$$

Hence we can do the following;

$$\text{(B-MUL)}\ \dfrac{\text{(B-ADD)}\ \dfrac{\text{(B-NUM)}\ \dfrac{}{3 \Downarrow 3} \qquad \text{(B-NUM)}\ \dfrac{}{2 \Downarrow 2}}{(3+2) \Downarrow 5} \qquad \text{(B-ADD)}\ \dfrac{\text{(B-NUM)}\ \dfrac{}{1 \Downarrow 1} \qquad \text{(B-NUM)}\ \dfrac{}{4 \Downarrow 4}}{(1+4) \Downarrow 5}}{((3+2) \times (1+4)) \Downarrow 25}$$

3. Extend the **big-step** semantics further to include *subtraction*. Remember that the numbers in the syntax of the language are $0, 1, 2, \ldots$ (no negative numbers).

How is an expression such as $(3-7)$ handled in your semantics? Have you made any arbitrary decisions about this? If so, what other options were available?