

Assessed Coursework 1

1. What are the free names and free variables of the following processes?

- (a) $P = (\nu c)(\bar{b}\langle c \rangle \mid b(x).P_1)$
- (b) $Q = (\nu b)(b(x).Q_1 \mid \bar{b}\langle c \rangle \mid x(y).Q_2)$
- (c) $R = (\nu a)(!a(x).\bar{c}\langle y \rangle \mid a(x).R_1 \mid b(y).\mathbf{0})$

2. Substitutions:

- (a) Apply $((\nu a, b)(\bar{b}\langle x \rangle \mid \bar{b}\langle a \rangle \mid !(\nu c)b(y).P))\{b/x, a/y\}$
- (b) Is the following application of a substitution correct? Write the justification: if **not**, write the reason.

$$((\nu a)(\bar{x}\langle x \rangle \mid a(x).(\nu a)\bar{y}\langle a \rangle))\{a/x, b/y\} = (\nu a)(\bar{a}\langle a \rangle \mid a(x).(\nu a)\bar{b}\langle a \rangle)$$

3. Are these processes structurally congruent? Write the justification: if **not**, write the reason; if **yes**, derive $P \equiv Q$ using the rules in the lecture notes.

- (a) $(\nu a)Q \mid P \mid !(P \mid (\nu a)Q)$ and $(\nu a)(P \mid Q) \mid !((\nu a)(P \mid Q))$
- (b) $(\nu a)\bar{c}\langle a \rangle \mid !(\bar{a}\langle x \rangle \mid b(y).\mathbf{0})$ and $\bar{a}\langle c \rangle \mid (\nu c)!(\bar{c}\langle x \rangle \mid b(y).\mathbf{0})$
- (c) $(\nu a)(\bar{c}\langle a \rangle \mid a(x).\bar{a}\langle a \rangle)$ and $(\nu a)(\bar{c}\langle a \rangle \mid b(x).\bar{b}\langle b \rangle)$

4. Write the reduction step by step using the rules in the lecture notes (you can omit some steps, such as the structural congruence).

- (a) $(\nu b)(a(x).\bar{x}\langle b \rangle) \mid !(\bar{a}\langle b \rangle \mid b(x).\mathbf{0})$
- (b) $!a(x).(\bar{b}\langle x \rangle \mid \bar{c}\langle x \rangle) \mid !b(y).(\bar{a}\langle y \rangle \mid c(y).\mathbf{0}) \mid \bar{a}\langle e \rangle$
- (c) $\bar{a}\langle a, b, c \rangle \mid !a(x, y, z).\bar{y}\langle x, z, y \rangle \mid !b(x, z, y).\bar{x}\langle x, y, z \rangle$
- (d) $\bar{a}\langle c \rangle \mid \bar{a}\langle d \rangle \mid \bar{a}\langle e \rangle \mid \bar{a}\langle f \rangle \mid \mathbf{NN}(a)$

where **New Name Generator** $\mathbf{NN}(a) \stackrel{\text{df}}{=} !a(x).(\nu b)\bar{x}\langle b \rangle$.