Due Friday, July 14, by noon, to Crowdmark.
All submitted work must be the student’s own.

(Revised: 10 July 2017)

**Question 1** (8 marks).
For each of the following, find a term $t$ such that the formula holds. Justify your answers in detail, with reference to the axioms Step1–Step15.

3. Q1 (a) $\text{Eval}(\langle \text{cond}, \langle \text{equal?}, e, e \rangle, e \rangle, \langle e, \langle e, e \rangle \rangle, t)$.
Q1 (b) \[ \text{Eval}(\langle y, x \rangle, \langle \langle y, \langle \lambda, \langle z \rangle, \langle \text{cons}(e, z) \rangle \rangle \rangle, \langle x, e \rangle), t) \].

(In your solution, you may use the abbreviation \( f = \langle \lambda, \langle z \rangle, \langle \text{cons}(e, z) \rangle \rangle \) when appropriate.)
Question 2 (16 marks).
Show that each of the following Hoare triples is satisfied under partial correctness where the domain is the natural numbers (including 0). Give all the needed details of your program annotation. For “implied” proofs, use ordinary arithmetic laws.

Q2 (a) \(\{ u \leq x \} \)
\[
\begin{align*}
&x = x + 1; \\
y = x; \\
x = x + 1; \\
z = x; \\
\{ (u \leq y) \land (u \leq z) \}
\end{align*}
\]
Q2 (b) \( \left\{ \tau \right\} \)

\[
\begin{align*}
y &= x ; \\
x &= x + 1 ; \\
z &= x \times y ; \\
\left( \exists u \left( (u + u) = z \right) \right)
\end{align*}
\]
Q2(c) \(\{ \tau \}\)
if \((x <= y)\) {
    \(z = y + y;\)
} else {
    \(z = x + x;\)
}
\((x + y) \leq z\)
Q2 (d) ⌊T⌋
   if ( y <= z ) {
      x = z - y ;
   } else {
      x = y - z ;
   }
   ⌋ (x ≥ 0) ∧ (((x + y) = z) ∨ (y = (x + z))) ⌋