1. Which one of the following sentences has the same meaning as "(if there is) no pain, (then there is) no gain"?
   a. Pain is sufficient for gain.
   b. There is pain unless there is no gain.
   c. Pain implies gain.
   d. There is gain when there is pain.

2. Which one of the following states satisfies $x < 4 \wedge (b[x] \neq 3 \rightarrow b[x] > b[0])$?
   a. $\{x = 1, b = (2,1,5,3,4)\}$
   b. $\{x = 2, b = (1,4,3,2,5)\}$
   c. $\{x = 3, b = (5,3,2,4,1)\}$
   d. $\{x = 4, b = (4,2,1,5,3)\}$

3. Which one of the following statements is equivalent to Java/C program fragment:

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while(++x>n) {y*=x++;}
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   a. $x \coloneqq x + 1; \textbf{while } x > n \textbf{ do } x \coloneqq x + 1; y \coloneqq y * x; x \coloneqq x + 1 \textbf{ od}$
   b. $x \coloneqq x + 1; \textbf{while } x > n \textbf{ do } y \coloneqq y * x; x \coloneqq x + 1; x \coloneqq x + 1 \textbf{ od}$
   c. $\textbf{while } x > n \textbf{ do } x \coloneqq x + 1; y \coloneqq y * x; x \coloneqq x + 1 \textbf{ od}; x \coloneqq x + 1$
   d. $\textbf{while } x > n \textbf{ do } y \coloneqq y * x; x \coloneqq x + 1; x \coloneqq x + 1 \textbf{ od}; x \coloneqq x + 1$

4. Let $W \equiv x \coloneqq 3; \textbf{while } x > 0 \textbf{ if } x \,\%\, 2 = 1 \textbf{ then } x \coloneqq x - 1 \textbf{ else } x \coloneqq x/2 \textbf{ fi do}$. What is τ where $\langle W, \sigma\rangle \rightarrow^* \langle E, \tau\rangle$?
   a. $\{x = 0\}$
   b. $\sigma[x \mapsto 0]$
   c. $\perp_e$
   d. $\perp_d$

5. Let $W \equiv \textbf{do } x > y \rightarrow x \coloneqq x - 1 \ \square\ x < y \rightarrow x \coloneqq x + 1 \textbf{ od}$. Which one of the following is a possible $M(W, \sigma)$?
   a. $\{\{x = 3,\ y = 4\}\}$
   b. $\{\{x = 0,\ y = 0\}\}$
   c. $\{\{x = -1,\ y = -3\},\ \{x = 2,\ y = 4\}\}$
   d. $\{\perp_d\}$

6. Which of the following states satisfies $\{x > 1\}\ \textbf{if } x > y \textbf{ then } x \coloneqq x - 1 \textbf{ fi}\ \{x = 1\}$?
   a. $\{x = 1; y = 2\}$
   b. $\{x = 2; y = 2\}$
   c. $\{x = 3; y = 4\}$
   d. $\{x = 4; y = 2\}$

7. Let $M(S, \sigma) = \{\tau\}$ where $\tau \in \Sigma_\perp$. Which of the following proposition about S must be true?
   a. $M(S, \sigma) \nvDash F$
   b. $M(S, \sigma) \vDash T$
   c. S is loop-free.
   d. S is deterministic.

8. Let $\vDash_{tot} \{x \geq 0\}\, S_1\, \{x \leq 1\}$ and $\vDash_{tot} \{x \leq 0\}\, S_2\, \{x \geq 1\}$. Which of the following triples must be valid under total correctness?
   a. $\{x \geq 0\}\, S_1; S_1\, \{x \leq 1\}$
   b. $\{x \leq 0\}\, S_2; S_2\, \{x \geq 1\}$
   c. $\{x \geq 0\}\, S_1; S_2\, \{x \geq 1\}$
   d. $\{x \leq 0\}\, S_2; S_1\, \{x \leq 1\}$

9. If deterministic program S diverges on σ, then which one of the following must be true for arbitrary q?
   a. $\sigma \vDash wlp(S, q)$
   b. $\sigma \vDash wp(S, q)$
   c. $\sigma \nvDash wlp(S, q)$
   d. None of the above.

10. Define predicate function $\mathrm{greatest}(a, b, c)$ which returns $True$ if and only if array a contains the greatest integer (or one the greatest integers) among arrays a, b and c. You may assume that a, b and c are all non-empty one-dimensional arrays of integers.

11. Calculate $wlp\ (IF,\ x = y)$, where $IF \equiv \textbf{if}\ x < y\ \textbf{then}\ x \coloneqq x + 1\ \textbf{else}\ y \coloneqq y - 1\ \textbf{fi}$. Do not logically simplify your solution.