1. Which of the following statements are true? Give examples to explain our answers.
   (a) Weakening of preconditions doesn't change the validity of a correct Hoare formula.
   (b) Strengthening of preconditions doesn't change the validity of a correct Hoare formula.
   (c) Weakening of postconditions doesn't change the validity of a correct Hoare formula.
   (d) Strengthening of postconditions doesn't change the validity of a correct Hoare formula.

2. Which of the following Hoare formulae are valid, and why? Give a counter example, if the formula is not valid.

   (a) $\{y \neq 0 \ \wedge \ x/y < 1\}$
   ```
   z := x/y
   ```
   $\{z < 1\}$

   (b) $\{x = N \ \wedge \ y = M \ \wedge \ z = O\}$
   ```
   x := y;
   y := z;
   z := x
   ```
   $\{x = N \ \wedge \ y = O \ \wedge \ z = M\}$

   (c) $\{X = 1 \ \vee \ Z = 0\}$
   ```
   if z=0
   then x := 0
   else x := 1 - x;
   endif;
   z := 1
   ```
   $\{x = 0 \ \wedge \ z = 1\}$

   (d) $\{x := 0\}$
   ```
   while x = 0 do
       x := x + 1
   endwhile
   ```
   $\{x = 1\}$

   (e) $\{True\}$
   ```
   while x>0 do
     x := x-1;
     y := x
   endwhile
   ```
   $\{x = 0 \ \wedge \ y = 0\}$

3. The following program computes the square on natural numbers (given by n) by repeated addition. Try to prove the partial correctness by checking, whether the given Hoare formula is valid.

   $\{n \geq 0 \wedge m = 0\}$
   ```
   k := 0;
   while k < n do
       k := k + 1;
       m := m + n
   endwhile
   ```
   $\{m = n \cdot n\}$

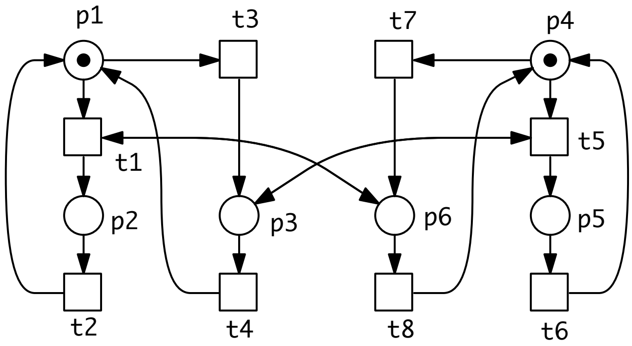
4. The following program calculates the sum and the difference of two natural numbers x and y. Try to prove the partial correctness by checking, whether the given Hoare formula is valid.

   $\{y \geq x\}$
   ```
   z := y;
   while x > 0 do
       x := x − 1;
       y := y + 1;
       z := z − 1
   endwhile
   ```
   $\{z = y - x \ \wedge \ y = y + x\}$

5. The following program sorts three numbers, stored in the variables x, y, and z, by assigning the smallest number to x, the second smallest to y, and the largest number to z. Try to prove the partial correctness by checking, whether the given Hoare formula is valid.

   $\{true\}$
   ```
   while x > y || y > z do
       if x > y then
           w := x;
           x := y;
           y := w
       else skip
       endif;
       if y > z then
           w := y;
           y := z;
           z := w
       else skip
       endif
   endwhile
   ```
   $\{sort[x, y, z] \equiv x \leq y \wedge y \leq z\}$

6. Consider the following Petri net.



(a) Construct the reachability graph for the given Petri net.

(b) Formulate the following assertions in CTL. Do they hold? Explain briefly why.

i. The maximum number of tokens on each place is 1.
ii. There are forever exactly two tokens in this Petri net.
iii. The sum of tokens on the places $p1, p2$ and $p3$ is forever constant.
iv. The sum of tokens on the places $p1, p3, p4$ and $p6$ is forever constant.
v. It is possible that the places $p3$ and $p6$ are marked at the same time.
vi. The places $p2$ and $p5$ are never marked at the same time.
vii. The initial marking is always reachable again.
viii. The initial marking will always be reached again for sure.
ix. The firing of $t1$ will immediately be followed by a firing of $t2$.
x. The firing of $t1$ will sometimes be followed by a firing of $t2$.
xi. The transition $t1$ can forever sometimes fire again.
xii. The transition $t1$ will forever fire again for sure.

(c) Consider the following assertions specified in CTL. Paraphrase them in English. Do they hold? Explain briefly why.

i. $\mathbf{EF}(p3 \wedge p6)$
ii. $\mathbf{AG}(\mathbf{not}(p2 \wedge p3))$
iii. $\mathbf{not}(\mathbf{EF}(p2 \wedge p3))$
iv. $\mathbf{AG}(\mathbf{EF}(p3 \wedge p4))$
v. $\mathbf{AG}(p1 \rightarrow \mathbf{EX}(p2 \vee p3))$
vi. $\mathbf{AG}(p3 \wedge p6 \rightarrow \mathbf{AF}(p1 \wedge p4))$