Concurrent Programming

Exercise Booklet 1: Traces

Note: For this booklet you must assume that assignment is atomic.

1. Assume that the **print** command is atomic. Show all possible traces of execution of the following program:

```
thread P: {          thread Q: {
  print("Hi");         print("Hi");
  print("Alice");      print("Bob");
}                    }
```

2. Draw the state diagram for the following programs. What values can x take at the end of the execution?

   a)

```
global int x = 0;

thread P: {              thread Q: {
  int local = x;           int local = x;
  local = local + 1;       local = local + 1;
  x = local;               x = local;
}                        }
```

   b)

```
global int x = 0;

thread P:              thread Q:
  x = x + 1;             x = x + 1;
```

3. Given the following program:

```
global int x = 0;
global int y = 0;

thread P:              thread Q:
  y = x + 1;             x = y + 1;
```

   a) Show an execution trace such that at the end $x = 2$ and $y = 1$.

   b) Is there a trace s.t. $x = y = 1$. Justify your answer.

4. Given the following program:

```
global int n = 0;

thread P: {            thread Q: {
  int local;             int local;
  repeat (5) {           repeat (5) {
    local = n;             local = n;
    n = local + 1;         n = local + 1;
} }                    } }
```

   - Show an execution trace in which the final value of n is 5.

5. Assume that f has an integer root, i.e., $f(x) = 0$ for some integer x. We now propose different programs for finding this root. We consider a program to be correct if both threads terminate once one of them has found a root. For each program indicate whether it is correct or not, justifying your answer.

   Program A:

```
global boolean found;
```

```
thread P: {                 thread Q: {
  int i = 0;                  int j = 1;
  found = false;              found = false;
  while (!found) {            while (!found) {
    i = i + 1;                  j = j - 1;
    found = (f(i) == 0);        found = (f(j) == 0);
} }                         } }
```

Program B:

```
global boolean found = false;

thread P: {                 thread Q: {
  int i = 0;                  int j = 1;
  while (!found) {            while (!found) {
    i = i + 1;                  j = j - 1;
    found = (f(i) == 0);        found = (f(j) == 0)
} }                         } }
```

Program C:

```
global boolean found = false;

thread P: {           thread Q: {
  int i = 0;            int j = 1;
  while (!found) {      while (!found) {
    i = i + 1;            j = j - 1;
    if (f(i) == 0)        if (f(j) == 0)
      found = true;         found = true;
} }                   } }
```

6. Consider the program:

```
global int n = 0;

thread P: {         thread Q: {
  while (n < 2)       n = n + 1;
    print(n);         n = n + 1;
}                   }
```

   a) Supply the execution traces that print the following sequences: 012, 002, 02.

   b) Should 2 necessarily appear in the output?

   c) How many times can 2 appear in the output?

   d) How many times can 1 appear in the output?

   e) How many times can 0 appear in the output?

   f) What is the length of the shortest sequence that can be exhibited?

7. Consider the program:

```
global int n = 0;

thread P:           thread Q:
  while (n < 1)       while (n >= 0)
    n = n + 1;          n = n - 1;
```

   a) Provide an execution trace in which the loop in the thread on the left is executed exactly once.

   b) Provide a trace in which the loop in the thread on the left is executed exactly three times.

   c) Describe a trace in which the loop in the thread on the left does not terminate.

8. Consider the program:

```
global int n = 0;
global boolean flag = false;
```

```
thread P:              thread Q:
  while (!flag)          while (!flag)
    n = 1 - n;             if (n == 0)
                             flag = true;
```

a) Provide an execution trace in which the program terminates.

b) What are the possible values of n when the program terminates.

c) Can the program not terminate?