

Concurrency & Parallelism

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1

1.1 A

```
x = x + 1;      x = y + 1;      z = x + y;
y = y + 1;      y = 2;          Listing 3: Thread 3
Listing 1: Thread 1  Listing 2: Thread 2
```

```
x: 1, 2
y: 1, 2, 3
z: 0, 1, 2, 3, 4, 5
```

1.2 B

```
x = x + 1;      y = y + 1;      x = 5;
Listing 4: Thread 1  Listing 5: Thread 2  y = x + 1;
Listing 6: Thread 3
```

```
x: 1, 5, 6
y: 1, 2, 6, 7
(x, y): (1, 1), (1, 2),
        (5, 1), (5, 6),
        (6, 1), (6, 7)
```

2

False The `volatile` keyword does not stop multiple threads from modifying the variable. The expression `x++` can be broken down into a read-modify-write sequence, which can be interleaved between threads.

3

1. Safety
2. Liveness
3. Liveness
4. Safety
5. Safety

4

1. G
2. A
3. D
4. B
5. C
6. F
7. H
8. E

5

Because the barrier will ensure that all threads wait for each other.

6

6.1 a

The number of combinations is $3! = 6$ and the possible combinations are:

- 1 3 5
- 1 5 3
- 3 1 5
- 3 5 1
- 5 1 3
- 5 3 1

6.2 b

1 3 5 2 4 6

6.3 c

3 6 2 5 4 1

7

```
public class BarrierN {
    private int a, b;

    public BarrierN (int howmany) {
        b = howmany;
        a = 0;
    }

    public synchronized void arrive() {
        a++;
        if (a < b) {
            this.wait();
            return;
        }
        this.notifyAll();
    }
}
```

8

8.1 a

In the line 11, the program read the values [20,25,30], before M_2 runs the credit statement, M_1 transferTo is able to execute completely and then M_2 credit statement runs, adding an old interest value.

8.2 b

The way it is written the program cannot deadlock, unless the client can have accounts that are references to other accounts.