

**Before Starting Homework**

- Do not upload to generative AI.
- Complete the Programming Assignment before beginning the written portion of the homework.
- Answer all questions below.
- **Type** answers and upload to Canvas in PDF format.

## 1 Question 1 : Producer-Consumer Example

Assume that I run your conditional wait producer/consumer methods. I create two producer threads and two consumer threads, as shown in the following Listing. Assume that a buffer `buf` was created before the Listing code snippet. The buffer can hold only a single value at a time.

Listing 1: Producer Consumer Example

```

1 pthread_t producer1, producer2;
2 pthread_t consumer1, consumer2;
3 data_t data1, data2;
4 data1.buf = buf; data1.val = 1;
5 data2.buf = buf; data2.val = 2;
6
7 // Create two producers and two consumers
8 pthread_create(&producer1, NULL, producer_thread, &data1);
9 pthread_create(&producer2, NULL, producer_thread, &data2);
10 pthread_create(&consumer1, NULL, consumer_thread, buf);
11 pthread_create(&consumer2, NULL, consumer_thread, buf);
12
13 // Wait for consumers and producers
14 int *val1, *val2;
15 pthread_join(producer1, NULL);
16 pthread_join(producer2, NULL);
17 pthread_join(consumer1, &val1);
18 pthread_join(consumer2, &val2);

```

The producer and consumer threads can be scheduled on your CPU cores in any order. Answer the following questions.

1. What are the possible values returned into `*val1` and `*val2`?
2. Describe an ordering in which the given threads are scheduled that results in both consumers sleeping at the same time.
3. Describe an ordering in which the given threads are scheduled that could result in one consumer calling `get` while the other consumer is sleeping.
4. In the previous example, after getting from the buffer, your consumer will signal for a sleeping thread to wake up. How do you guarantee that this signal will only wake up a sleeping producer rather than the sleeping consumer?

5. Your code should have `while` loops around the conditional waits. If they were instead `if` statements, the code could break. Describe a scenario where, assuming you instead used `if` statements, one of your consumers would return an incorrect value.