

Answer **ANY TWO** of the following three questions:

1. (Architecture) Draw a simplified circuit for the Boolean function F using only NOR and NOT gates:

$$F(a, b, c, d) = \Sigma(0, 1, 2, 4, 5, 6, 8, 9, 12, 13, 14)$$

2. (OS #1) Consider a virtual memory system in which physical memory has exactly three frames. Consider the following page reference string:

0, 3, 1, 2, 3, 2, 0, 1, 2, 3, 0

For each of the following page replacement strategies, show which references will cause page faults and show the contents of the three frames at the time of each fault. Assume the frames are initially empty. You do not need to show the first three faults caused by demand paging.

- a. Optimal
- b. First-In, First-Out
- c. Second-Chance
- d. Least Recently Used

3. (OS #2) Consider the following correct solution to the bounded-buffer producer-consumer problem, where there are N buffers, and the functions `producer()` and `consumer()` are run concurrently.

```
1  semaphore mutex = 1;    // initial value of semaphore is 1
2  semaphore full = 0;    // # of occupied slots
3  semaphore empty = N;  // # of available slots
4
5  void producer() {
6      while (true) {
7          produce();
8          wait(empty);
9          wait(mutex);
10         append();
11         signal(mutex);
12         signal(full);
13     }
14 }
15 void consumer() {
16     while (true) {
17         wait(full);
18         wait(mutex);
19         take();
20         signal(mutex);
21         signal(empty);
```

```
22     consume();
23     }
24 }
```

For each of the following pairs of program line numbers, what would be the potential effects (if any) of swapping the two lines of the program?

- a. 8 and 9
- b. 20 and 21