| **Department of Computer Science** | **Operating Systems** |
| **VU University Amsterdam** | **21.12.2017** |

This exam consists of two pages. No calculator, pencil, or open books allowed. Concise answers!

1 Instructions related to accessing I/O devices such as printers are typically privileged instructions (i.e., they can be executed in kernel mode but not in user mode). Give a reason why these instructions are privileged. Support your answer with an example that shows why having privileged instructions is important. *10pt*

2 After issuing a CTRL+C sequence from the keyboard, the active shell program dumps some debug output and keeps running. What happened? When would you expect the CTRL-C to termination the shell program instead? (Give *two* possible scenarios). *10pt*

3 What is the difference between a mutex and a spin lock? When would you use one or the other? Is a semaphore related to a mutex or a spinlock? *10pt*

4 Assume the following program is run in 1,000 concurrent processes, with `IO=1` in the first process and `IO=0` in the other 999 processes. All the processes run at the same priority and are scheduled using a round-robin scheduling policy on a single CPU. As you attempt to provide input from the terminal to the first process, you notice the process is poorly responsive. Answer the following questions: *10pt*

   – How do you characterize the first vs. the other processes from a scheduling point of view?

   – How do you explain the poor responsiveness of the first process?

   – How would you change the scheduling policy to improve the responsiveness of the first process?

```
1   int x;
2   int running = 1;
3   int sum = 0;
4
5   while (running) {
6     if (IO) {
7       x = read_int_from(stdin);
8       printf(''Successfully read integer %d \n'', x);
9     }
10    else {
11      x = 1;
12    }
13    sum += x;
14  }
```

5 A computer has 32-bit virtual addresses and 4-KB pages. The program and data together fit in the lowest page (0–4095) The stack fits in the highest page. How many entries are needed in the page table if traditional (one-level) paging is used? How many page table entries are needed for two-level paging, with 10 bits in each part? *10pt*

6 An operating system uses a buddy allocator to manage memory with (initially) one large chunk of 256 pages of 4KB each. All allocation requests are powers of 2 and allocations for sizes less than one page are rounded up to 4KB. Finally, given a choice, the allocator prefers to allocate page frames with the lowest physical address. What is a minimum-length sequence of allocations and deallocations that may lead to the following memory use of physical memory: *10pt*

   – the first 384 KB (96 page frames) of physical memory is free;

- the next 132 KB (from 384–516 KB) is allocated;

- the next 12 KB (from 516–528 KB) is free;

- the remainder of memory (from 552–1MB) is allocated;

7   A UNIX file system has 4-KB blocks and 4-byte disk addresses. What is the maximum file size if i-nodes contain 10 direct entries, and one single, double, and triple indirect entry each (providing the right formula is sufficient)?   *10pt*

8   Does memory-mapped I/O consume any virtual and/or physical memory? How about I/O ports? Explain.   *10pt*

9   A system is provided with 7 Blu-Ray disks (BD), 3 printers (PR), 4 tape drives (TD), and 2 plotters (PL). In total, **process A** needs 5 BD, 1 PR, 1 TD, and 1 PL, **process B** needs 2 PR, 1 TD, and 2 PL, **process C** needs 4 BD, 2 PR, and 1 TD, **process D** needs 1 BD, 1 PR, and 1 TD, 1 PL, and **process E** needs 2 BD, 1 PR, and 1 TD, Assume that the deadlock avoidance algorithm considers the following allocations:

- Process **A** has 3 BD, 1 TD, and 1 PL;

- Process **B** has 1 PR

- Process **C** has 1 BD, 1 PR, and 1 TD;

- Process **D** has 1 BD, 1 PR, and 1 PL;

- Process **E** has nothing.

Use the banker's algorithm (aka the generalized safe state detection algorithm) to determine whether the system could lead to deadlock (show the current allocation matrix and request/needs matrix while doing so).

10pt

10 What is the difference between full virtualization and paravirtualization? Which do you think is harder to do? Explain your answer.   *10pt*