| Department of Computer Science | Operating Systems |
| VU University Amsterdam | 28.05.2015 |

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

1 What is the difference between exokernel-based and microkernel-based operating system architectures? *8pt*

2 What is the relationship between C library calls, system calls, and message passing primitives in a multi-server operating system such as MINIX 3? *6pt*

3 On early computers, every byte of data read or written was directly handled by the CPU (i.e., there was no DMA—Direct Memory Access). What implications does this organization have for multiprogramming? *6pt*

4 Give a sketch of how an operating system that can disable interrupts could implement semaphores on a uniprocessor system. *6pt*

5 Using a sample execution run, show how the following concurrent program can come to a deadlock with N unconsumed items. *6pt*

```
1  process producer()          1  process consumer()
2  {                           2  {
3    while(true)               3    while(true)
4    {                         4    {
5      produce_item();         5      if (count == 0)
6      if (count == N)         6        sleep();
7        sleep();              7      remove_item();
8      enter_item();           8      count = count - 1;
9      count = count + 1;      9      if (count == N-1)
10     if (count == 1)         10       wakeup(producer);
11       wakeup(consumer);     11     consume_item();
12   }                         12   }
13 }                           13 }
```

6 In which thread organization does the operating system schedule only processes rather than individual threads? Mention one advantage and one disadvantage of such a thread organization. *8pt*

7 An alternative to interrupts is polling. Are there any circumstances you can think of in which polling is a better choice? *6pt*

8 What is the essential difference between block and character devices? Can a single device fall in both categories at the same time? *6pt*

9 Why is the Banker's algorithm rarely used in practice? Are there more practical alternatives? Support your answer with an example. *8pt*

10 A computer with a 32-bit address uses a two-level page table. Virtual addresses are split into a 9-bit top-level page table field, an 11-bit second-level page table field, and an offset. How large are the pages and how many are there in the address space? *6pt*

11 Least-recently used (LRU) page frames are often best to be evicted from memory, if there is a need to do so. Describe a technique that approximates keeping track of such page frames and give an example in which your technique may result in nonoptimal page replacement decisions. *6pt*

12 Two memory-intensive user programs, one with a small working set and one with a large working set, are running on a system with software-managed TLB. Speculate on whether switching to hardware-managed TLB will improve performance for each process. *8pt*

13 Free disk space can be kept track of using a free list or a bitmap. Disk addresses require D bits. For a disk with B blocks, F of which are free, state the condition under which the free list uses less space than the bitmap (assume BLOCK_SIZE ≫ D). For D having the value 16 bits, express your answer as a percentage of the disk space that must be free. *6pt*

14 When a buffer is returned to the block cache, it can either be prepended or appended to the LRU list. Explain under which conditions which choice is made. *6pt*

15 Describe the steps required for the operating system to perform the `unlink` system call. *8pt*