Department of Computer Science	**Operating Systems**
VU University Amsterdam	**04.02.2016**

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

1 Which of the following instructions should be allowed only in kernel mode? Note: more than one may be correct.

(a) Disable all interrupts.

(b) Read the time-of-day clock.

(c) Set the time-of-day clock.

(d) Change the memory map.

8pt

2 What is the difference between system calls and C library calls? Can a full program be written by using only system calls and no C library calls? If so, what are the consequences? *8pt*

3 Disabling interrupts used to be a standard technique for protecting critical sections in single-processor operating systems. Will this technique also work for an operating system designed for a multicore processor? What other techniques would you consider on a multicore processor? *9pt*

4 Consider the following piece of C code. How many child processes are created upon execution of this program and why? *8pt*

```
1 int main() {
2   fork();
3   fork();
4   return 0;
5 }
```

5 If FIFO page replacement is used with four page frames and eight virtual pages, how many page faults will occur with the reference string `0172327103` (i.e., a process referencing, in order, virtual page `0`, then `1`, then `7`, etc.) if the four frames are initially empty? Now repeat this problem for LRU. In both cases, list the virtual page numbers mapped to concrete page frames after each page fault (e.g., {`0,1,-,-`} if only virtual pages `0` and `1` are mapped to concrete page frames). *8pt*

6 What is copy-on-write? How can this technique help in optimizing the implementation of `fork()`? Will this technique help at all when `fork()` is not immediately followed by `exec()`? *9pt*

7 Explain how hard links and soft links differ with respect to i-node allocations. *8pt*

8 Does the on-disk ”log” have similar purposes in log-structured and journaling filesystems? Motivate your answer. *8pt*

9 Explain the difference between memory-mapped I/O and port-mapped I/O. Can both techniques be supported at the same time? *9pt*

10 In which of the four I/O software layers is each of the following done and why?

(a) Computing the track, sector, and head for a disk read.

(b) Writing commands to the device registers.

(c) Checking to see if the user is permitted to use the device.

(d) Converting binary integers to ASCII for printing.

8pt

11 A system has four processes (i.e., A B C D) and five allocatable resources (i.e., R1 R2 R3 R4 R5). Based on the current allocation and maximum needs as follows, what is the smallest value of x for which this is a safe state (i.e., a state which can guarantee there is some scheduling order in which every process can run to completion without deadlocking) and why? *8pt*

Process	Allocated					Maximum					Available				
-	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
A	1	0	2	1	1	1	1	2	1	3	0	0	x	1	1
B	2	0	1	1	1	2	2	2	1	1					
C	1	1	0	1	0	2	1	3	1	0					
D	1	1	1	1	0	1	1	2	2	1					

12 `pthread_mutex_lock()` can be called by a running POSIX thread to lock a mutex. Assuming there is only one thread running, can the following code result in a deadlock? Illustrate your answer in light of the four conditions that must hold for there to be a resource deadlock. *9pt*

```
1 void thread_lock() {
2   /* ... */
3   pthread_mutex_lock(my_mutex);
4   pthread_mutex_lock(my_mutex);
5   /* ... */
6 }
```