CSE 121: Operating Systems Architecture and Implementation
Fall Quarter, 2003
FINAL EXAM

Instructor: Alex C. Snoeren

Name ____________________________

Student ID ____________________________

Question	Score	Points
1		20
2		20
3		15
4		20
5		20
6		15
7		20
8		20
9		15
10	10	10
Total		175

This exam contains ten questions of differing point values. Each question is clearly labeled with its value. Please answer all questions in the space provided. You have three hours to complete this exam. As with any exam, I suggest you read through all the questions first before answering any of them. Note that the final question is a freebie; you will receive full credit regardless of your answer. I would, however, appreciate your feedback if you have time remaining after completing the remainder of the exam.

Happy Holidays!

1. (20 pts) Always/Sometimes/Never. Determine whether each of the following statements is always, sometimes, or never true. No explanation is necessary; partial credit will not be awarded.

   a) The `sbrk()` system call accepts negative parameter values.

   b) LFS is less likely to leave the file system in a corrupted state than FFS after a system crash.

   c) Caching disk blocks does not increase perceived read latencies.

   d) Prefetcing disk blocks decreases perceived read latencies.

   e) The "write cost" of any data block in a log-based file system is no less than one.

   f) Increasing disk block size increases (up to the maximum single operation size supported by the disk) disk performance for large reads/writes.

   g) The optimal replacement algorithm replaces the least recently used page.

   h) In any given epoch, GMS replaces the globally oldest pages.

   i) Exokernels provide applications with highly optimized abstractions of physical hardware.

   j) For any given benchmark, Soft Updates will perform fewer disk writes than FFS.

2. (15pts) Define each of the following terms in one or two sentences. Where applicable, do more than just expand the acronym.

   a) process group

   b) thrashing

   c) dropped rotation

   d) ballooning

   e) system call trampoline

   f) TLB

3. (10pts) Short answers. Give concise responses to each of the following questions.

a) What is the difference between a micro-kernel and an exokernel?

b) List two improvements FFS made over the original UNIX file system.

c) In project two, what was the purpose of the SIGVTALRM signal handler?

d) What purpose do placeholders serve in LRU-SP?

e) Why, for a fixed (large) number of processors, do multiple instances of IRIX running in DISCO VMs out-perform native IRIX.

f) How did Mach maintain binary compatibility with BSD applications?

g) What are the two main obstacles to efficient VMM implementation?

4. (20pts) In class, we discussed both the File Allocation Table (FAT) filesystem used by DOS and the UNIX inode-based file system, which was replaced by the Fast File System. Answer the following questions about these file systems.

   a) How were free blocks accounted for in the DOS FAT? (That is, what sort of data structure was used to record the free blocks, and how was it traversed?)

   b) Why, in FFS, are inodes and data blocks kept in separate areas of the disk?

   c) Describe the trade-offs involved in deciding when to store a file on a different cylinder group than the rest of the directory.

   d) Identify a performance problem that fragments introduce for small files in FFS. How could it be avoided?

5. (20pts) Answer the following questions about the figure attached to the back of this exam, reproduced from Figure 1 in the “Journaling Versus Soft Updates” paper discussed in class. Recall that “LFFS” refers to a journaling implementation of the Fast File System, and “WAFS” refers to an LFFS that maintains the journal in a separate, stand-alone write-ahead file system. “sync” and “async” refer to whether or not the journal is written synchronously or not, respectively, and “1” and “2” refer to the number of physical disks used.

   a) What is the fundamental difference between FFS, LFFS-wafs-1sync, LFFS-wafs-2sync, and the others that explains their poor performance for small (< 32KB) files?

   c) Why does this performance gap disappear as the file size gets larger?

   b) What is responsible for the decrease in performance around 100 KB for all of the measured systems?

   d)) Give two reasons why the performance of Soft Updates often decreased when the size of the benchmark increased. That is, when the benchmarks operated on either larger data sets or for longer periods of time, the relative throughput of Soft Updates (as compared to LFFS) often decreased considerably when compared to smaller data sets over shorter periods of time.

6. (15 pts) Compare and contrast the mechanisms used in GMS and VMware ESX to support virtual memory. In particular, discuss the goals of their respective page replacement schemes, the techniques used to achieve their goals, and any differences in the information available to the two systems about memory usage.

7. (20 pts) Answer the following questions about the two major micro-kernel OSes we discussed in class, Mach and L4.

   a) Give two advantages of micro-kernels over monolithic ones.

   b) What were the five central abstractions provided by Mach?

   c) It is often said that the rise of micro-kernels gave birth to a cottage industry of research on fast IPC. Briefly describe why IPC performance matters for micro kernels.

   d) Give one example of how L4 improved performance when relative to Mach.

8. (20 pts) Briefly describe the strategy you used in your memory allocator for project 3. Discuss its strengths and weaknesses with regard to both space and time efficiency. List two other strategies you considered, and argue for your choice.

9. (15 pts) Answer the following questions about virtual machine monitors like DISCO and VMware that use direct execution; that is, VMMs that run CPU instructions on the actual hardware rather than emulating them.

   a) Briefly describe how protected system calls (i.e., those instructions that require supervisor privileges) are handled by a virtual machine monitor.

   b) What's the difference between a "physical" address and a "machine address"? Explain how virtual addresses inside a particular VM are mapped to machine addresses in DISCO. What data structures did DISCO need to maintain?

   c) One popular method of improving the performance of commodity OSes on VMMs is to provide special device drivers. Describe two ways in which DISCO used special disk and/or network drivers to improve the performance of IRIX.

10. (10 pts) You will receive full credit for this question regardless of how you respond, so DO NOT ANSWER IT UNTIL YOU ARE FINISHED with the remainder of the exam. There is no penalty if you don't get to it.

   a) What topic covered in this course did you find the most interesting?

   b) What topic did you find least interesting, and why?

   c) How long did you spend on each project? Which one was your favorite?

   d) Was there an operating systems topic you wish we had covered?

   e) Is there anything you'd suggest the professor to do differently next time he teaches this course?