Department of Electrical Engineering and Computer Science

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

6.828 Fall 2014

Quiz II

All problems are open-ended questions. In order to receive credit you must answer the question as precisely as possible. You have 120 minutes to finish this quiz.

Write your name on this cover sheet AND at the bottom of each page of this booklet.

Some questions may be harder than others. Read them all through first and attack them in the order that allows you to make the most progress. If you find a question ambiguous, be sure to write down any assumptions you make. Be neat. If we can't understand your answer, we can't give you credit!

THIS EXAM IS OPEN BOOK AND OPEN LAPTOP, but CLOSED NETWORK.

Please do not write in the boxes below.

I (xx/10)	II (xx/15)	III (xx/10)	IV (xx/10)	V (xx/15)	VI (xx/5)	VII (xx/5)	VIII (xx/15)	IX (xx/5)	Total (xx/90)

Name:

Email address used on submission site:

I Ext3

1. [5 points]: Ext3 supports several modes, including journaled and ordered. Consider the workload of an application overwriting the same file n times: each iteration opens the file, writes all the blocks in the file, closes the file, and syncs the file. The file is b blocks large. For this workload, estimate how many disk writes of data blocks Ext3 will perform in journaled mode? How many in ordered mode? (Explain your answer briefly.)

2. [5 points]: Describe an application that would want to use ext3 in journaled mode, and explain briefly what would go wrong if the application were to use ordered mode.

II OS organization

This question explores the differences between 3 OS organizations: monolithic, microkernel, and exokernel.

3. [5 points]: Identify a subsystem out of JOS that provides a good example of an exokernel organization and briefly explain why it is a good example.

4. [5 points]: Identify a subsystem out of JOS that provides a good example of a microkernel organization and briefly explain why it is a good example.

5. [5 points]: Identify a subsystem out of JOS that provides a good example of a monolithic-style subsystem and briefly explain why it is a good example.

III Singularity

In Singularity only one process can have a pointer to an object in the exchange heap. Ben proposes to modify Singularity to maintain a reference count for each object in the exchange heap and collect the object when the reference count is zero. When a process dies, he arranges to decrease the reference counter for each object in the exchange heap to which the dying process has a pointer.

In Ben's design several processes can share an object in the heap. This would allow Ben to use the exchange heap, for example, for a shared buffer cache.

6. [5 points]: What problem does Singularity try to solve by disallowing shared objects in the exchange heap? (Briefly explain your answer.)

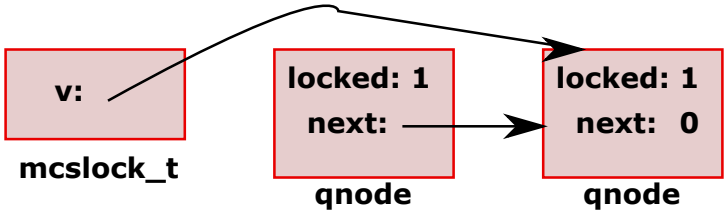
7. [5 points]: How would you implement a shared buffer cache in Singularity as described in the paper (i.e., without Ben's modification)? (Briefly explain your answer.)

IV Scalable locks

The following code is an implementation of MCS locks, which was handed out in lecture:

```
1  static inline void
2  mcs_init(mcslock_t *l)
3  {
4          l->v = NULL;
5  }
6
7  static inline void
8  mcs_lock(mcslock_t *l, volatile struct qnode *mynode)
9  {
10         struct qnode *predecessor;
11
12         mynode->next = NULL;
13         predecessor = (struct qnode *)xchg((long *)&l->v, (long)mynode);
14
15         if (predecessor) {
16                 mynode->locked = 1;
17                 asm volatile("":::"memory")    // memory barrier
18                 predecessor->next = mynode;
19                 while (mynode->locked)
20                         nop_pause();
21         }
22 }
23
24 static inline void
25 mcs_unlock(mcslock_t *l, volatile struct qnode *mynode)
26 {
27         if (!mynode->next) {
28                 if (cmpxchg((long *)&l->v, (long)mynode, 0) == (long)mynode)
29                         return;
30                 while (!mynode->next)
31                         nop_pause();
32         }
33         ((struct qnode *)mynode->next)->locked = 0;
34 }
```

This code creates the following structure when two cores are waiting for a given lock:



8. [5 points]: Using the picture, explain how MCS locks avoid collapse when a lock is contended by many cores.

The instruction `asm volatile("":::"memory")` (line 17) is a memory barrier, which tells the compiler to not reorder memory accesses past this barrier.

9. [5 points]: Describe a race if this instruction was omitted and the compiler was allowed to reorder instructions past the memory barrier.

V Virtual machines

10. [5 points]: Extended page tables translate guest physical to host physical addresses. Suppose we have two kernels (K_1 and K_2), which each map guest virtual addresses 0 to n to guest physical addresses 0 to n, where n is 4 Mbyte. What mapping should a virtual machine monitor setup using extended page tables for K_1 and K_2 so that the monitor can multiplex and run both kernels?

11. [5 points]: In IX, when a network application calls `run_io` how many protection boundary changes (e.g., ring 3 to ring 0, non-root to root) happen? (Briefly explain your answer.)

12. [5 points]: In IX, when IX reads or writes the NIC queue, how many protection boundary changes happen? (Briefly explain your answer.)

VI Multitasking and Locks in JOS

Alyssa P Hacker has successfully implemented fine-grained locks for her lab 4 challenge in 6.828. The page allocator, the console driver, the scheduler, and the inter-process communication (IPC) code each have their own spin lock.

Later, when testing her fork code with 4 CPUs, Alyssa writes the following code fragment:

```
if((a = fork()) == 0) {
    ipc_recv(&a, 0, 0);
    cprintf("Process␣One!\n");
    exit();
}
if((b = fork()) == 0) {
    ipc_recv(&b, 0, 0);
    cprintf("Process␣Two!\n");
    exit();
}
ipc_send(a, 0, 0, 0);
ipc_send(b, 0, 0, 0);
cprintf("Process␣Three!\n");
```

13. [5 points]: Assume that there are no other environments running. In what order will the strings be printed? (Explain briefly why.)

VII Disk block cache

Consider the following block cache code in JOS:

```
1  #define PTE_SYSCALL     (PTE_P | PTE_W | PTE_U)
2
3  // Write the cached block at virtual address addr back to disk
4  void
5  flush_block(void *addr)
6  {
7          uint32_t blockno = ((uint32_t)addr - DISKMAP) / BLKSIZE;
8
9          if (addr < (void*)DISKMAP || addr >= (void*)(DISKMAP + DISKSIZE))
10                 panic("flush_block␣of␣bad␣va␣%08x", addr);
11
12         if (!va_is_mapped(addr) || !va_is_dirty(addr))
13                 return;
14
15         // Write the disk block and clear PTE_D.
16         addr = ROUNDDOWN(addr, BLKSIZE);
17         ide_write(blockno * BLKSECTS, (void*) addr, BLKSECTS);
18         sys_page_map(0, addr, 0, addr, uvpt[PGNUM(addr)] & PTE_SYSCALL);
19 }
20
21 // Sync the entire file system.  A big hammer.
22 void
23 fs_sync(void)
24 {
25         int i;
26         for (i = 1; i < super->s_nblocks; i++)
27                 flush_block(diskaddr(i));
28 }
29
30 static void
31 bc_pgfault(struct UTrapframe *utf)
32 {
33         <Sanity checks on faulting address and the super block...>
34         <Allocate new page...>
35
36         if ((r = ide_read(blockno * BLKSECTS, addr, BLKSECTS)) < 0)
37                 panic("in␣bc_pgfault,␣ide_read:␣%e", r);
38
39         if ((r = sys_page_map(0, addr, 0, addr, uvpt[PGNUM(addr)] & PTE_SYSCALL)) < 0)
40                 panic("in␣bc_pgfault,␣sys_page_map:␣%e", r);
41 }
```

Recall that the x86 automatically sets the “dirty bit” in the page table entry of any page that is written by software.

Name:

Ben Bitdiddle is working on the block cache for lab 5, but doesn't know that his implementation of `sys_page_map()` is buggy. When Ben's `sys_page_map()` maps a page, the page table entry is not modified if the physical address of the mapped page is unchanged.

14. [5 points]: For testing purposes, Ben writes an program that simply reads every file in the file system. Ben notices that, after running his test program, a call to `fs_sync()` takes several seconds to complete even though no data was written. Why does `fs_sync()` take so long?

VIII File descriptors in JOS

Ben Bitdiddle would like to implement a new function, called `reset_fds()`, which will close all of a JOS environment's open file descriptors.

15. [5 points]: How should this function be implemented in JOS? What functionality should be added to the kernel (e.g. via a system call) and what modifications should be made to user space?

Ben's implementation of `reset_fds()` contains the following line of code:

```
memset(FDTABLE, 0, MAXFD*PGSIZE);
```

(Recall that the arguments to `memset` are the start address, fill value, and length to be filled.)

Ben writes a program to test `reset_fds()` and runs it from the shell. Unfortunately, two bad things happen when the test program calls `reset_fds()`: the program page faults, and console input and output stop working in the shell.

16. [5 points]: Why does the test program page fault?

17. [5 points]: Why do console input and output stop working in the shell?

IX 6.828

We'd like to hear your opinions about 6.828, so please answer the following questions. (Any answer, except no answer, will receive full credit.)

18. [1 points]: Grade 6.828 on a scale of 0 (worst) to 10 (best)?

19. [2 points]: Any suggestions for how to improve 6.828?

20. [1 points]: What is the best aspect of 6.828?

21. [1 points]: What is the worst aspect of 6.828?

End of Quiz II — Enjoy the break!

Name: