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Problem	Points	Lost	Gained	Running Total	TA
1	1				
2	19				
3	20				
4	20				
5	20				
6	20				
Total	100				

******* SHORT ANSWERS WE MEAN IT! *******

You may ask for clarification but you are ultimately responsible for the answer you write on the paper. If you make any assumptions state them.

Please look through the entire test before starting. WE MEAN IT!!!

******* NOTE: M = 10^6 K = 10^3 Mi = 2^{20} Ki = 2^{10} ********

Illegible answers are wrong answers.

Show your work in the space provided to get any credit for problem-oriented questions.

Good luck!

1. (1 point, 1 min) (don't worry you get 1 point regardless of what you say!)
"Opum Gangnam style" refers to
(a) the fiscal cliff
(b) Former Senator Alan Simpson's new YouTube video
(c) GOP's theme song
(d) how one wastes time on the Internet
(e) how do I know, I am at Tech, and taking your course, remember!?
(f) _____ (fill in your own thoughts!)

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Cache

2. (19 points, 20 min)

a) (6 points)

A fully associative cache is initially empty, has only **four** blocks, and uses an **LRU replacement policy**. The processor performs a total of eight accesses, to memory blocks A, B, C, D, A, E, B, and C, in that order. For each of these accesses, specify (by filling in the table below) whether it is a cache hit or a cache miss, type of miss (cold/capacity/conflict), and the memory block evicted (if any). **Note: capacity miss dominates over conflict; cold dominates over capacity**.

Memory Access	Hit/miss	Type of miss	Block evicted from cache
A			
B			
C			
D			
A			
E			
B			
C			

b) (5 points)In a modern processor with TLB, physically indexed physically tagged cache, and physical memory, **using a figure** show and explain the path of a **read memory access** (from the generation of the virtual address to delivering the instruction or data to the CPU). **You get zero points if there is no figure**. You have to show how the virtual and physical addresses are interpreted by the TLB, the cache, and the physical memory to complete their respective functions.

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c) (3 points) If a cache uses write-through policy, it can use two different strategies for dealing with write misses: ***write-allocate***, or ***no-write-allocate***. Explain the difference between the two strategies.

d) (5 points) Consider a **4-way set associative** cache:

- Total **data size** for the cache = **64 KiB** (note: Ki = 1024)
- CPU generates 32-bit byte-addressable memory addresses
- Each memory **word** consists of **4 bytes**
- The cache **block size** is **16 bytes**
- The cache has **one valid bit per block**
- The cache uses **write-back** policy with **one dirty bit per word**

Compute the meta data associated with **each cache line** (note: with 4-way set-associativity, there are **4 blocks in each cache line**)

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Input/Output and Disk

3. (20 points, 20 min)

a) (5 points) Given the following specification for a disk drive:

Seek time	=	4 ms
Rotational speed	=	6000 RPM
Platters	=	2
Surface per platter	=	2
Tracks per surface	=	1024
Sectors per track	=	128
Recording density	=	256 bytes per sector

What is the time to read 4 consecutive sectors from the disk? Recall that the time to read any sector on the disk is given by the sum of the seek time, the time needed to get the head over the desired sector, and the time to read the sector itself.

b) Given the following:

Total number of cylinders in the disk	=	200 (numbered 0 to 199)
Current head position	=	cylinder 23
Current requests in order of arrival	=	22, 17, 55, 35, 25, 78, 90

Assume **cylinder 0 is the outermost** one and **199 is the innermost** one on the disk.

i) (3 points) Show the schedule for C-LOOK for the above requests

ii) (3 points) Show the schedule for SSTF

c) (3 points) Given the following specifications for a disk drive:

Seek time	=	8 ms
Rotational speed	=	7500 RPM
Platters	=	4
Surface per platter	=	2
Tracks per surface	=	20
Recording density	=	256 bytes per sector

Assume a **zoned bit** recording with 3 zones
- Zone 3 (outermost): 8 tracks, 20 sectors per track
- Zone 2: 7 tracks, 14 sectors per track
- Zone 1 (innermost): 5 tracks, 10 sectors per track

What is the total capacity of this drive?

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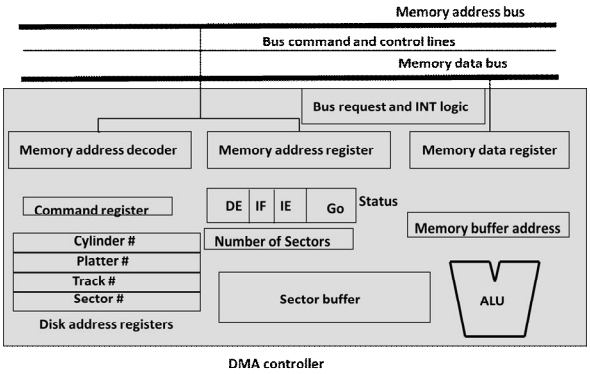
d) (3 points) Shown below is a simplified sketch of a DMA controller for a disk.



Answer the following questions with respect to the above schematic:

i) what is the need for a sector buffer in the controller?

ii) The ALU in the figure supports basic arithmetic operations (addition, subtraction). what is the need for the ALU in the controller?

iii) DE is a 1-bit flag in the status register that signifies “Data Overrun Error”. What is the purpose of this flag?

e) (1 point) Disk drive is a synchronous I/O device. Explain why.

f) (1 point) DMA controller bypasses the CPU to transfer data to/from memory directly from/to the device. Yet, it is designed with the capability to interrupt the CPU. Explain why.

g) (1 point) Keyboard is an asynchronous I/O device. Explain why.

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File Systems

4. (20 points, 20 min)

a) (6 points)

Notes:

- Unix "**touch <file>**" command creates a zero byte new file or updates the timestamp of the named file
- Unix "**ln <file1> <file2>**" command creates a hard link
- Unix "**ln –s <file1> <file2>**" command creates a sym link
- Unix "**rm** <file>" removes the named file

In the following table, assume **none of the files exist to start with** in the current directory. Fill in the table. The reference count in the table pertains to the i-node that is affected by the command in that row. If a new i-node is created, show the old reference count for that i-node as 0.

Command	New i-node created (yes/no)	Reference count old	new
touch f1	Y	0	1
touch f2	Y	0	1
ln f1 f3	N	1	2
ln –s f3 f4	Y	0	1
ln f4 f5	N	1	2
rm f3	N	2	1

Use this area for rough work for this question. Draw i-nodes for the files to help you figure things out.

b) (2 points) FAT allocation strategy results in (circle ONE choice that captures ALL the TRUE statements in the following list)

(1) External Fragmentation
(2) Internal fragmentation
(3) Ability to grow the file easily
(4) Large allocation overhead
(5) {1 and 2}
(6) {2 and 3}
(7) {2, 3, and 4}
(8) None of the above

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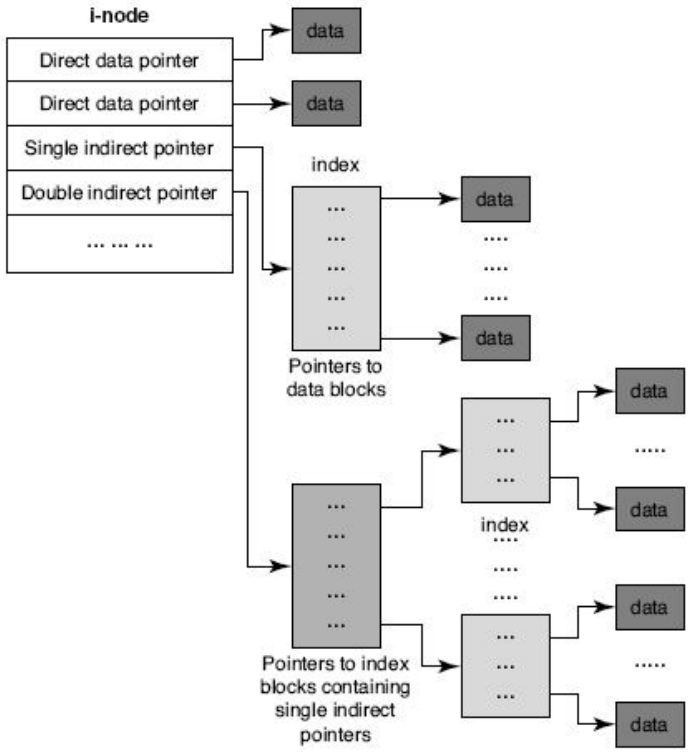
c) (**NOTE Mi = 2^{20}**)
Given the following:
Size of index block = 512 bytes
Size of Data block = 4096 bytes
Size of pointer = 8 bytes (to index or data blocks)

The i-node consists of
2 direct data block pointers,
1 single indirect pointer, and
1 double indirect pointer.

Note that the index blocks and data blocks are allocated on a need basis. An index block is used for the top-level i-node as well as for the index blocks that store pointers to other index blocks and data blocks (see Figure).



i. (2 points) How many pointers does each index block contain?

ii. (2 points) How many data blocks are used to store a 20 MiB file?

iii. (3 points) How many index blocks (including the i-node for the file) are needed to store a 20 MiB file?

iv. (3 points) What is the largest file size that can be supported in this file system?

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d) (2 points) Multilevel indexed allocation strategy results in (circle ONE choice that captures ALL the TRUE statements in the following list)
(1) External Fragmentation
(2) Internal fragmentation
(3) Ability to grow the file easily
(4) Inefficiency for accessing small files
(5) {1 and 2}
(6) {2 and 3}
(7) {2, 3, and 4}
(8) None of the above

Parallel Systems

5. (20 points, 20 mins)
a) (5 points) (choose one correct choice in each of the following)

I. A thread
1. Lives until it terminates on its own
2. Terminates ONLY when the top-level procedure it started in terminates
3. Terminates ONLY when main terminates
4. Terminates when EITHER the top-level procedure or main terminates

II. Ensuring that all the threads of a given process share an address space in an SMP is
1. Impossible
2. Trivially achieved since the page table is in shared memory
3. Achieved by careful replication of the page table by the operating system for each thread
4. Achieved by the hardware providing cache consistency

III. Livelock
1. Is a condition where threads are not using mutex locks
2. Is a special kind of lock that allows a thread to busy-wait
3. Is a condition where one or more threads are blocked waiting for an event that will never happen
4. Is a condition where one or more threads are busy-waiting for an event that will never happen

IV. To get exclusive access to a resource the following code is used:
while (state == BUSY) thread_cond_wait (c, m);
state = BUSY;
Replacing the "**while**" by "**if**" in the above construct
1. Will ALWAYS result in violating the intended synchronization
2. Will NEVER result in violating the intended synchronization
3. May SOMETIMES result in violating the intended synchronization

V. Keeping the TLBs consistent in an SMP
1. Is the responsibility of the user program
2. Is the responsibility of the hardware
3. Is the responsibility of the operating system
4. Is impossible

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b) (5 points) A thread executes the following code:

```
thread_mutex_lock(lock);
   while (bufavail == 0){
      thread_cond_wait(c, m);
   }
   /* Enter: critical section */
   /* code for critical section */
      …
      …
   /* Exit: critical section */
thread_mutex_unlock(m);
```

In the above code, **m** and **c** are OS supported mutual exclusion lock and condition variables, respectively. "bufavail" is a variable local to the thread code. The OS has no visibility nor control over this variable.

What are the "**invariants**" when the thread enters the critical section?

c) (3 points)You have to implement a ticket function. Shown below is the code that shows the desired functionality. Fix this function so that any number of threads can call the function and obtain a unique and distinct value for the ticket.

```
int ticket()
{
   static int ticket = 0;

   ticket++;
   return(ticket);
}
```

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d) (3 points) Given the following procedure called binary-semaphore:

```
static int shared-lock = 0; /* global variable to both T1 and T2 */

/* shared procedure for T1 and T2 */
int binary-semaphore(int L)
{
   int X;

   X = test-and-set (L);
   return(X);
}
```

Two threads T1 and T2 execute the following statement simultaneously:

```
   MyX = binary_semaphore(shared-lock);
```

where **MyX** is a *local variable* in each of T1 and T2.

What are the possible values returned to T1 and T2?

e) (4 points) Explain the difference between **write-update** and **write-invalidate** protocols for solving the multiprocessor cache coherence problem.

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Networking

6. (20 points, 20 min) (**SHORT ANSWERS WE MEAN IT!)**

a) (3 points) A message is broken up into 1024 packets and sent using stop-and-wait transport protocol.

i) How many packets need to be buffered in the protocol stack of the sender? Give a one sentence reasoning.

ii) What is the minimum number of bits needed in the sequence number to ensure reliable transmission? Give a one sentence reasoning.

b) (6 points) Give a one sentence answer on how each of the following transport layer concerns are handled:

i) Out of order delivery of packets?

ii) Packet loss?

iii) Packet corruption?

c) (2 points) Give two important differences between TCP and UDP.

d) (3 points) Assume that the network loses 1 in 10 packets, on an average. For a message that consists of 200 packets (and ignoring fractional losses of packets), determine the total number of packets sent by the sender to successfully complete the transmission.

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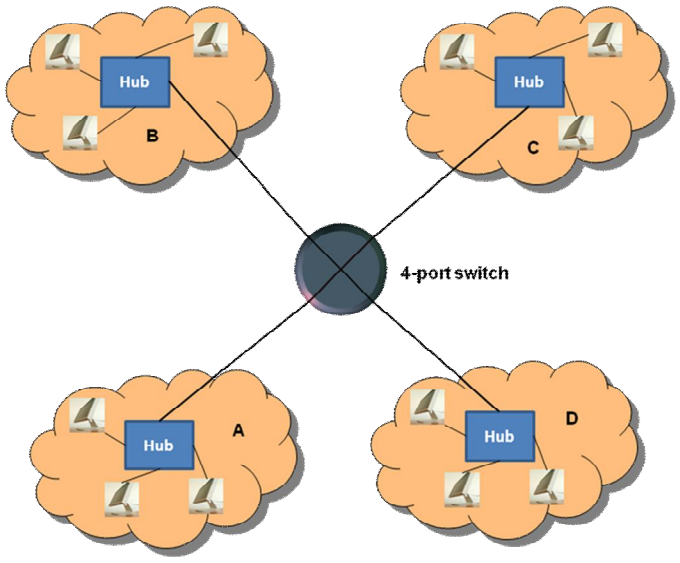
e) (2 points) What is the purpose of the “adjustable window size” in the sliding window protocol?

f) (2 points) Give the two main functions performed by the network layer of the protocol stack.

g) (2 points) How many collision domains exist in the figure shown below?



Your answer: