CS 423, Spring 2016
Midterm (total = 25 points)

This is an open-book/notes take-home midterm. Please work on this midterm independently. Please *print ONLY the answer sheet at the end of this document* (don't forget to fill-in your answers in the space provided).

The answer sheet is due in hard copy at start of class, on Wednesday, March 16th

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Q1: Copy onto the answer sheet only the *system calls* among the calls listed below: **(1 point)**

fread() exit() getuid() fork() rand() mount()

Q2: Consider the table below, where rows indicate tasks (smaller task numbers imply higher priority) and columns indicate resources. A cell at row X and column Y is set to 1 if task X uses resource Y. Each resource is protected by its own mutex. When a task needs resource Y, it executes a Lock(Y) operation on the corresponding mutex. When it is done, it executes Unlock(Y). The priority *ceiling* algorithm is used together with *rate monotonic* scheduling. Indicate which of the lock/unlock sequences below are possible and which are impossible according to your understanding of how the priority ceiling algorithm and the rate monotonic scheduling policy work. Assume that (i) at the start of each sequence, no locks are held, and (ii) each sequence is a chronologically sorted list of *consecutive* lock/unlock operations, but (iii) it may be that other lock/unlock operations occur after the end of each sequence, that are not shown. Assume that no other blocking occurs in the system except on the mutexes below. Assume also that no locks are held by a task invocation after its finish time.

	Resource R1	**Resource R2**	**Resource R3**	**Resource R4**	**Resource R5**
Task T1		**1**			
Task T2					**1**
Task T3			**1**	**1**	
Task T4	**1**	**1**	**1**		**1**

In the answer sheet, next to each subcase simply write "possible" or "impossible". **(2 points)**

a) T3 locks R3, T2 locks R5, T1 locks R2 **possible**
b) T4 locks R1, T3 locks R4, T3 unlocks R4 **possible**
c) T2 locks R5, T1 locks R2, T2 unlocks R5, T1 unlocks R2 **impossible**
d) T4 lock R2, T2 locks R5 **impossible**

Q3: A 64-bit machine has a 32 GB main memory and a page size of 4KB. Assume that 8 bytes are needed for each entry in the page table.
a) How many bits do you need to represent a page number? **(1 point)** **52 bits (will mark 23 correct too)**
b) If you use a single-level page table on this machine, how long will it be (in Bytes)? **(1 point)** 2^{55}

Q4: In a 64-bit architecture which type of page table would you recommend: Single level page table, 2-level page table, or an Inverted page table? (Just name your choice) **(1 point)** **Inverted**

Q5: How many real-time priority levels exist in the Linux kernel? **(1 point)** **100 (99 is OK)**

Q6: In a virtual memory system, the time it takes to access the TLB is 1 nano-sec, whereas the time it takes to access physical memory is 9 nano-sec. The TLB hit ratio is 90%. If a single-level page table is used, what is the average virtual memory access time? **(1 points)** **10.9 nanosec**

Q7: Name a Linux system call that sends a signal to a process. **(1 point)** **Kill**

Q8: A processor consumes 100 Watt when running at 4GHz and 40 Watt when running at 1GHz. A CPU-centric task is being executed (i.e., you can neglect the time spent on memory accesses). What percentage of energy would be saved in executing this task at a 1 GHz clock speed compared to executing the same task at a 4 GHz clock speed? (Note: If energy consumption increases, indicate the increase as negative savings. For example, a savings of -100% would mean that energy consumption doubles.) Assume the processor sleeps when not executing tasks. Assume that no energy is consumed when sleeping and assume there is no wakeup cost. **(1 point)** **-60%**

Q9: Answer Q8 again, except this time assume that the task is memory-centric. In other words, time spent on the CPU is negligible next to the time spent on memory accesses. **(1 point)** **60%**

Q10: In the Linux423 operating system, all locks have unique IDs. A restriction is added that disallows any one process from requesting a lock with a lower ID than the maximum of all lock IDs that the same process currently holds. Hence, each process can only acquire locks in increasing order of IDs. Assume that nothing else can block a process except waiting on a lock. Can deadlocks occur in Linux423? Please answer YES or NO. **(1 point)** NO

Q11: The following page references are seen when executing a task: A, B, C, A, D, E, F, B, C. Assume that the main memory has room for only 4 frames. Nothing is initially loaded in memory.
a) If the LRU replacement policy is used, how many page faults will occur? **(1 point)** **8**
b) If an optimal (clairvoyant) demand-paging policy is used, how many page faults occur? **(1 point)** **6**

Q12: Which contiguous storage placement policy attempts to utilize the smallest unutilized gap (that can accommodate the new program) when fitting a new program? **(1 point)** **Best Fit**

Note: For the multiple-choice questions below (13-22), please copy ONLY the letter (a, b, c, or d) corresponding to the *best* answer onto the answer sheet. (1 point/question)

Q13: A processor consumes 16 Watt when running and 1 Watt when asleep. The wake-up cost is 0.3 Joule. What is the shortest sleep interval that does not increase energy consumption over staying awake? **(1 point)**

a) **20 ms**
b) 50 ms
c) 100 ms
d) 200 ms

Q14: The energy consumption, E, of a processor follows the function: $E = 4 f^2 + 1/f$, where f is its frequency (expressed as a fraction of the maximum value). For example, running the processor at f=0.6 means running it at 0.6 the maximum frequency. Which value of f would you recommend to run the processor at in order to minimize energy consumption?

a) 0.125
b) 0.25
c) 0.4
d) **0.5**

Q15: Which of the following statements best describes a TCP SYN attack (also called a SYN flood)?

a) It is an attack against a former vulnerability of TCP that got fixed by the invention of TCP congestion control
b) It is an attack against network routers that causes them to route traffic into a black hole
c) It is an attack where a sender (the attacker) floods a receiver's buffer with content constituting a malicious program, then uses a kernel vulnerability to pass control to that program
d) **It is a form of denial of service attacks against end-hosts that causes excessive amounts of overhead in the kernel**

Q16: In Linux, what is the name of the default time sharing scheduling policy?

a) **SCHED_OTHER**
b) SCHED_RR
c) SCHED_DEADLINE
d) SCHED_FIFO

Q17: You are hired by NASA to develop software for the next Lunar Roving Vehicle. The OS on the vehicle uses a scheduling policy similar to SCHED_FIFO in Linux. One of the design choices lies in selecting an appropriate library for implementing locks and synchronization. You compare multiple available libraries with the purpose of finding one that minimizes the phenomenon of priority inversion. Which of the following libraries would you choose?

a) A library that implements the priority inheritance protocol
b) **A library that implements the priority ceiling protocol**
c) A library that keeps thread priorities constant at all times (including when they are blocking other threads by virtue of locking resources needed by others)
d) A library that increases the priority of a thread if it blocks waiting on a resource locked by another thread

Q18: A processor has a perfect sleep state where no energy is consumed, and a capability to scale down its frequency while keeping its voltage fixed. The processor has a zero wakeup cost. Which of the following will minimize the energy consumed in executing a given piece of computation? You may assume that the computation in question is CPU-bound (i.e., is carried out primarily inside the CPU).

a) **Operate at the highest frequency then go to sleep**
b) Operate at the lowest frequency then go to sleep
c) Compute the optimal frequency (which may be different from the highest and the lowest) and operate at that frequency then go to sleep
d) Operate at the lowest frequency while keeping awake at all times

Q19: In Linux, you want to schedule a group of processes strictly in a fixed priority order (no time slices and no proportional fair shares). Which policy should you choose?

a) SCHED_OTHER
b) SCHED_RR
c) SCHED_DEADLINE
d) **SCHED_FIFO**

Q20: Which of the following architectures have the largest effective memory access time? Assume that the TLB hit ratio is 80% and that the TLB access time is five times faster than the main memory access time.

- **a)** An architecture with a two-level page table and a TLB
- **b)** An architecture with a single-level page table and a TLB
- **c)** An architecture with an inverted page table and a TLB
- **d) An architecture with an inverted page table and no TLB**

Q21: Which of the following conditions are more likely to cause thrashing? In the conditions below, you can interpret a loop with a "short body" to mean that it accesses a small amount of data in each iteration, and interpret a loop with a "large body" to mean that it accesses a large amount of data in each iteration.

- **a)** Executing a single (flat) loop with a short body and a high iteration count
- **b) Executing a single (flat) loop with a large body and a high iteration count**
- **c)** Executing a 2-level nested loop, where the inner loop has a short body and a high iteration count, whereas the outer loop simply calls the inner loop again.
- **d)** Executing a nested loop with the following structure: The outer loop makes a very large number of function calls in sequence. Each called function executes a (different) loop with a short body and a high iteration count.

Q22: Why is the Translation Lookaside Buffer (TLB) implemented using associative memory?

- **a)** Because associative memory hardware implements binary search instead of a linear search when looking for table entries that match a specified virtual page address
- **b)** Because associative memory hardware hashes virtual memory addresses into indexes that allow efficient retrieval of corresponding physical addresses from the TLB.
- **c)** To avoid use of indexing, which is a computationally slow operation (whereas the TLB needs to be fast)
- **d) Because the TLB has a lot fewer entries than the number of virtual pages in a program's address space, which motivates use of hardware with a parallel search capability (for an entry that matches a key).**

The End

Please fill out, print, and hand in only the answer sheet below

(Turn page over)

Name: _____

NetID: _____

Please print and return this single sheet only.

Q1:

Q2.a:

Q2.b:

Q2.c:

Q2.d:

Q3.a:

Q3.b:

Q4:

Q5:

Q6:

Q7:

Q8:

Q9:

Q10:

Q11.a:

Q11.b:

Q12:

Q13:

Q14:

Q15:

Q16:

Q17:

Q18:

Q19:

Q20:

Q21:

Q22:

_____ Good Luck _____