Please answer all required questions (all questions other than those marked bonus credit, which are optional). After each question, you will see a suggested time budget which I use if this question were to be asked on a midterm. This time budget is there to help you prepare for the midterm.

Submission: Please submit a printed (or legible if handwritten) hardcopy of the homework in class on the due date. If you are using one or more slack days for this assignment, please mark your assignment with the number of slack days used and hand it to me or the TA (slip it under my door if I am not there).

Problem 1: (9 minutes) Briefly explain the following terms

- TLB miss
- One shot resource allocation
- Protection requirement for memory management

Problem 2: (10 minutes) Discuss the any 3 of the following potentially wrong statements.

1. Implementing segmentation for a paged system makes sense just like implementing paging for a segmented system does (e.g., as is used in the Intel Architecture in the last homework)
2. Deadlock detection is the most liberal algorithm that prevents deadlock from occurring
3. Translating memory addresses at load time makes sharing memory more difficult
4. In virtual memory, when a page is swapped from memory to disk, the cache entries for it must be found and invalidated
5. The TLB holds page table entries for valid pages only

Problem 3: (15 minutes) Show an example that illustrates each of the following:

1. A safe state
2. An unsafe state
3. Deadlock avoidance being more liberal than one shot allocation
4. Best-fit performing worse than worst-fit for dynamic memory partitioning

Problem 4: (10 minutes)
(a) Consider an implementation of an OS where processes sometimes do not exit cleanly and resources they have such as file descriptors are sometimes not released. Eventually, some processes will ask for resources but there is an insufficient amount. Is this case an example of deadlock?

(b) After winning his second MVP, Alex Rodriguez is unhappy with his contract and wants to negotiate a better deal and threatens with a holdout (he will not play unless he is paid more). News sources report that Rodriguez and the Yankees cannot reach an agreement and are deadlocked. Does this situation represent deadlock according to the CS definition?

(c) Assuming that the situation in (b) was an instance of deadlock, consider the following scenario. The player and the club agree on a new contract, but for half the raise that the player wanted. What type of solution to deadlock does this represent?
Problem 5: (20 minutes)
Paging extends fixed partitioning to allow multiple partitions per process. Similarly, segmentation does the same for dynamic partitioning. Recall that the buddy system, like fixed and dynamic partitioning, is an approach to contiguous memory allocation.
(a) Develop a multiple partition memory management approach based on the Buddy system. Clearly show how address translation is carried out.
(b) Discuss how protection and sharing can be supported for such a system.
(c) Discuss the advantages and disadvantages of such a system compared to paging and segmentation.
(d) Are there issues in implementing virtual memory for this system?

Problem 6: (8 minutes) Answer the following questions.
(a) What hit ratio on the TLB is needed to bring the average address translation time to 10% of its value without TLB, assuming TLB accesses are free.
(b) What happens if the size of the TLB is smaller than the number of active pages (memory pages that the program is currently referencing) at any given time?
(c) What happens if the size of the allocated physical memory for a process is smaller than the size of the active pages?

Problem 7: (15 minutes)
Consider a paged memory system where the frame size is 4Kbytes (2^{12} bytes). The page table size is restricted to 2^{16} entries. In addition, the size of the physical memory is 2^{15} frames.
(a) What is the maximum memory size (logical) that a process can have?
(b) How many processes can fit in memory if each of them takes up 1/4 of its maximum size
(c) Consider a computer where the page tables are kept in memory. The cost of accessing memory is 500nsec. A TLB is used to optimize translation; the cost of accessing the TLB is 50nsec. What should the TLB hit rate be to make the average translation time 75nsec?

Problem 8: (25 minutes) An OS uses a multiple level feedback scheduler with 3 round-robin levels. The quantum for the 3 levels are 1, 2, and 4 time units respectively. Assume that we have 6 jobs that arrive at time 0 with burst lengths of 8, 2, 1, 3, 10, 4. The jobs are listed in the order they arrive (the one with length 8 arrived first).
(a) Show the Gantt chart for these processes. What is the response time and the normalized turnaround time?
(b) What are the advantages/disadvantages of this scheduler vs. Round Robin scheduling?
(c) What are the advantages of Multiple Level Feedback relative to Shortest Job First scheduling; are there any given that SJF minimizes the average wait time?
(d) Consider a scheme called selfish round robin scheduling (SRR), which delays newly arrived processes until they catch up in priority to existing processes. Specifically, processes that are waiting build up priority at a rate x, while processes that are running build up priority at a rate y where x is bigger than y. A new process is only admitted when its priority catches up with the priority of any running process. SRR appears to do the opposite of the multi-level feedback algorithm above, yet both approaches have been proposed. Can you explain this apparent paradox?

Problem 9: (bonus; 30 minutes)
This problem is bonus because you will have to read ahead to some stuff we have not covered yet. Consider a system where logical memory is 2^{38} bytes, and physical memory is 2^{30} bytes.
memory system is paged. There is a total of $2^{16}$ frames in the physical memory. The system is multiprogrammed (more than one process).

(a) What is the page size?

(b) You are trying to decide whether to use an inverted page table or a two level page table for this system. Assume a page table entry is 8 bytes, while an inverted page table entry is 16 bytes. Assume that in a two level page table scheme, every process needs the directory as well as 4 pages of the page table in memory all the time. Typically, you will have 16 processes active in the system. Which page table organization do you pick to minimize the amount of memory taken up by the page tables? Show your work

(c) The system has a TLB and a cache that is indexed on physical addresses and uses a two level page table. Show in painful detail the process of a memory access showing the alternatives at every step. Also, discuss what is implemented in hardware and what is implemented in software.

(d) What needs to be done when a context switch occurs in terms of memory management in the system described in part (c)?