Name: **Student Id:**

CMPSCI 377: Operating Systems

Exam 2: Memory Management

April 20, 2010

General instructions:

- This examination booklet has 9 pages.
- Do not forget to put down your name and student number on the exam books.
- The exam is closed book and closed notes.
- Explain your answers clearly and be concise. Do not write long essays.
- You have 90 minutes to complete the exam. Be a smart test taker, if you get stuck on one problem go on to the next. Don't waste your time giving details that the question does not request.
- Show your work. Partial credit is possible, but only if you show intermediate steps.
- Good luck.

---

1. **Contiguous Memory Allocation** (20 points)

   (a) **Relocation**

   - (5pts) Explain the difference between static and dynamic relocation.

- (5 pts) List three advantages of static relocation over dynamic relocation. Is any special hardware necessary to support static relocation? Explain your answer.

(b) **Fragmentation**

- (4pts) What are external and internal fragmentation?

- (6pts) Consider a memory allocation scheme that uses the segmentation policy. Assume that the size of physical memory is 64MB. On an average, how much memory do you expect to lose to: (i) external fragmentation, and (ii) internal fragmentation? Explain your answer.

2. **Paging** (20 points)

(a) Consider a memory management scheme that uses pure paging (i.e., the entire process is in memory at all times). Let the size of physical memory be 1024 bytes, and let us assume that the size of a memory frame (and a page) is 16 bytes.

- (4 pts) What is the maximum size of a process in such a system? How large should the page table be to accommodate this process?

- (10 pts) Draw a picture showing how a virtual address generated by the CPU is translated to a physical address. Indicate clearly how many bits are used for the page number and how many for the offset. Assume byte level addressing. (Note: $1024 = 64 * 16$).

(b) (6 pts) What is a *translation look-aside buffer (TLB)*? Do you need a TLB for correct execution of programs?

3. **Segmentation and Segmented Paging** (30 points)

(a) (10 pts) *Segmentation:* What is the purpose of using segments within a program? What hardware features do you need to implement a pure segmentation scheme?

(b) (20 pts) *Performance of Segmented Paging.* This question asks you to compute the effective memory access time (*ema*) in symbolic terms for different hardware implementations of segmented paging with and without virtual memory. Let *ma* be the time to read or write a value in memory. Define other terms as you need them. First assume that the process, the segment table and the page table fit and stay in memory while the program executes, and there is no TLB.

i. (4 pts) What is the *ema* for this system?

ii. (4 pts) Now assume there is a TLB. What is the *ema* for this system? Include *l*, the time for the TLB look up in your equation.

iii. (6 pts) Now consider a virtual memory system with a TLB where the process can grow larger than the memory, and the pages may not always be in memory. What is the *ema* now? Assume that the page table and the segment table are always in memory.

iv. (6 pts) Now what is the *ema* for the same system except that the page table entry itself may not be in memory? Assume that the segment table is always in memory.

4. **Page Replacement Algorithms** (15 points)

Consider a demand paged virtual memory scheme that used the LRU page replacement algorithm. Assume that a certain process has five pages A,B,C,D and E and is allocated three page frames.

- (6pts) Indicate the contents of each page frame for the reference string: $ABCDABEABCDE$.

	A	B	C	D	A	B	E	A	B	C	D	E
frame 1												
frame 2												
frame 3												

- (6pts) Indicate the contents of each page frame if four page frames are allocated the the process.

	A	B	C	D	A	B	E	A	B	C	D	E
frame 1												
frame 2												
frame 3												
frame 4												

- (3pts) How many page faults do you see in each case? Why does the number of page faults show this behavior (i.e., an increase or a decrease)?

5. **Deadlocks** 15 points

- (10 pts) Consider the following system state for four processes P_0, P_1, P_2 and P_3, and three resources A, B and C. Using Bankers algorithm, determine whether the following state is safe or unsafe. Explain your answer.

	Max			Allocation			Available		
	A	B	C	A	B	C	A	B	C
P_0	0	0	1	0	0	1			
P_1	1	7	5	1	0	0			
P_2	2	3	5	1	3	5			
P_3	0	6	5	0	6	3			
total				2	9	9	1	5	2

- (5pts) List the necessary conditions for a deadlock.