

CSE 4509: Operating Systems
Class Test 3, Time: 1 hour

1. A system has a virtual memory system with a 16-bit virtual address space. The physical memory uses a 20-bit address space. The system uses a page size of 4KB. A process is executed and generates the following sequence of virtual memory accesses. Each access is performed on one or two virtual addresses, which are given in different formats, such as decimal(0d), binary(0b), octal(0o), and hexadecimal(0x).

1. LOAD R1, 0b1100101010101100
2. STORE R2, 0x0FAD
3. ADD R1, 0d52134, 0x1234
4. LOAD R3, 0o2477
5. SUB R4, 0xCDEF, 0d14321
6. MOV R5, 0b111100001111

Now **find out the desired physical addresses for the given virtual addresses in the above code**. Use the following page table to get the PFN for the corresponding VPN. The page table entries are written in decimal here. **[6 marks]**

VPN	0	2	4	8	12	14	15
PFN	2	0	15	10	20	6	4
valid	1	0	1	0	1	1	1

2. Imagine a computer system with a physical memory that **can hold up to 6 pages**. This system uses virtual memory management with a page replacement policy based on the Least Recently Used (LRU) algorithm. You are provided with a sequence of page references and **must simulate the behavior of the system as it processes this sequence**. **[6 marks]**

The sequence of page references is as follows:

3, 2, 10, 8, 3, 7, 0, 7, 3, 4, 0, 2, 8, 9, 10, 4, 0

3. Consider a 32-bit system running an OS that uses hierarchical page tables to manage virtual memory. Assume that logical and physical pages are of size 2KB. The system has 1 GB of physical RAM. Assume that each page table entry requires an additional 10 bits (beyond the frame number) to store various flags. Assume page table entries are rounded up to the nearest byte. Now answer the following questions:
 - a) What is the size of the offset? [1]
 - b) How many virtual pages are there in the virtual memory? [1]
 - c) How many bits are required for a VPN? [1]
 - d) How many bits are required for a PFN? [1]
 - e) Find the size of a single page table. [2]
 - g) Design a multi level page table for the above virtual memory. [2]

Bonus Question (Total 3 marks)

Answer the following questions with the correct option. Each question's marks are provided at the right side.

1. A certain page table entry in the page table of a process has the valid bit set but the present bit unset. Describe what happens on a memory access to a virtual address belonging to this page table entry.
 - (a) What happens at the TLB? (**hit/miss/cannot say**) [0.5]
 - (b) Will a page fault occur? (**yes/no/cannot say**) [0.5]
2. When a page fault occurs, the operating system always swaps out a page from memory to disk before bringing the requested page into memory. (**True/False**) [0.5]
3. In a hierarchical paging system, the page table itself is paged. (**True/False**) [0.5]
4. **Find out which of the following statements are true:** [1]
 - (a) Hierarchical paging increases the cost of context switches.
 - (b) Hierarchical paging requires more memory accesses to translate a virtual address compared to a flat page table.
 - (c) In hierarchical paging, all levels of the page table are always kept in main memory.
 - (d) Hierarchical paging allows dynamic resizing of page tables.