Practice Questions on Memory Management

1. Consider a process running on a system with a 52-bit CPU (i.e., virtual addresses are 48 bits in size). The system has a physical memory of 8GB. The page size in the system is 4KB, and the size of a page table entry is 4 bytes. The OS uses hierarchical paging. Answer the following questions:

    a) What is the size of the offset?
    b) How many virtual pages are there in the virtual memory?
    c) How many bits are required for a VPN?
    d) How many bits are required for a PFN?
    e) Find the size of a single page table.
    f) Design a multi level page table for the above virtual memory.

2. Consider a system with paging-based memory management, whose architecture allows for a 4GB virtual address space for processes. The size of logical pages and physical frames is 4KB. The system has 8GB of physical RAM. The system allows a maximum of 1K (=1024) processes to run concurrently. Assuming the OS uses hierarchical paging, calculate the maximum memory space required to store the page tables of all processes in the system. 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. Consider the memory required for both outer and inner page tables in your calculations.

3. Consider a system with a 6 bit virtual address space, and 16 byte pages/frames. The mapping from virtual page numbers to physical frame numbers of a process is (0,8), (1,3), (2,11), and (3,1). Translate the following virtual addresses to physical addresses. Note that all addresses are in decimal. You may write your answer in decimal or binary.
    (a) 20
    (b) 40

4. Consider a 64-bit system running an OS that uses hierarchical page tables to manage virtual memory. Assume that logical and physical pages are of size 4KB and each page table entry is 4 bytes in size.
    (a) What is the maximum number of levels in the page table of a process, including both the outermost page directory and the innermost page tables?
    (b) Indicate which bits of the virtual address are used to index into each of the levels of the page table.
    (c) Calculate the maximum number of pages that may be required to store all the page table entries of a process across all levels of the page table.

5. Consider the following information:

   Virtual Address Space: 24 bits
   Physical Address Space: 32 bits
   Page Size: 4 KB (2^12 bytes)
   Page Table:

VPN	PFN	Valid bit
0x001	0x0210A	1
0x002	0x011B0	0
0x003	0x032A0	1
0x004	0x00111	1
0x005	0x0121A	0
0x006	0x12AC1	1
0x007	0x000AB	1
0x008	0x01A2D	0
0x009	0x10101	0

Translate the following virtual addresses to physical address:
a) 0000 0000 0011 0000 1010 1111
b) 0000 0000 0101 0000 0000 0101
c) 0000 0000 0111 0001 1111 0111