Question 1. [10 points] why is the protection of processes’ memory space important? Describe a scenario where absence of memory protection leads to problems.

Question 2. [20 points] **The following table shows the core map of a virtual memory system, which has a page size of 100.**

|  |  |  |
| --- | --- | --- |
| Frame number | Process ID | Page number |
| 0 | 1 | 2 |
| 1 | 1 | 1 |
| 2 | 2 | 1 |
| 3 | 3 | 0 |
| 4 | 1 | 3 |

a. To which physical address does virtual address 130 of process 1 map? If this virtual address does not map to any physical address, write ”does not map”.

b. To which physical address does virtual address 17 of process 2 map? If this virtual address does not map to any physical address, write ”does not map”.

c. Which virtual address of which process maps to physical address 50?

Question 3. [30 points] Consider a system where the virtual memory page size is 1KB (1024 bytes), and main memory consists of 4 page frames, which are empty initially. Now consider a process, which requires 8 pages of storage. At some point during its execution, the page table is as shown below:

|  |  |  |
| --- | --- | --- |
| Virtual page # | Physical page # | Valid Flag |
| 0 |  | No |
| 1 |  | No |
| 2 | 2 | Yes |
| 3 | 3 | Yes |
| 4 |  | No |
| 5 |  | No |
| 6 | 0 | Yes |
| 7 | 1 | Yes |

1. [10 points] List the virtual address ranges that will result in a page fault.
2. [20 points] Give the following **ordered** references to the virtual addresses (i) 4500, (ii) 8000, (iii) 3000, (iv) 1100, please calculate the main memory (physical) addresses. If there is a page fault, please use LRU based page replacement to replace the page. How which page will be affected and compute the physical addresses after the page fault. We assume the reference string is 2 4 7 3 0 4 3 0 7 5 0 7 6 0 2 3 6 4 7 6 3 2 before the new reference.

Question 4. [20 points] Given a computer system with the following paging based addressing for virtual addresses. Please answer the following questions:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 2 bits | 5 bits | 5 bits | 5 bits | 7 bits |

1. [5 points] What is the size of the virtual address space?
2. [5 points] What is the page size?
3. [5 points] What is the maximum number of pages for a process?
4. [5 points] Assume the TLB access time a, memory access time b, and page fault processing time c, given the system has a TLB hit ratio of 99% and page fault rate of 1%. Please formulate the effective memory access time.

Question 5. [20 points] Consider a system with 1MB of available memory and requests for 40KB, 398KB, 15KB, and 20KB. The system is using Buddy Allocation Algorithm.

**a)**. (15 points) Show the amount of memory allocated for each request and the state of memory after each request. Assume there is no memory release.

**b).** (5 points) Why does internal fragmentation occur with buddy allocation? How much internal fragmentation exists in this scenario?

**c).** (5 points) Why does external fragmentation occur with buddy allocation? How much external fragmentation exists in this scenario?