Operating System (H)
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Assignment 5

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Question 1

(1)

i.

For the first access, since the TLB is empty, we need to access the page table, then the physical memory. Thus, the total time is

$$t = 10\text{ns} + 2 \times 100\text{ns} = 210\text{ns}$$

ii.

Since the valid bit of the page table entry is 0, the data is not present in the physical memory, and we need to access the disk. After we fetch the data from the disk, the instruction is executed once again, and it will find the data in TLB and then access the physical memory. Thus, the total time is

$$t = 10\text{ns} + 100\text{ns} + 10^8\text{ns} + 10\text{ns} + 100\text{ns} = 10^8 + 220\text{ns}$$

iii.

The third access is similar to the first access, and the total time is

$$t = 10\text{ns} + 2 \times 100\text{ns} = 210\text{ns}$$

(2)

When the second access triggers page fault, the least recently used page is replaced. Since we accessed page `122H` in the first access, page `233H` is the least recently used page. Thus, the page table is updated as follows

Virtual Page	Physical Page	Valid Bit
0	`233H`	1
1	`122H`	1
2		0

Then, the third access will trigger another page fault. Now the least recently used page is page `122H`, and the page table is updated as follows

Virtual Page	Physical Page	Valid Bit
0	`233H`	1
1		0
2	`122H`	1

Thus, after all three accesses, the corresponding physical address for Virtual address `0x0555H` is `0x233555H`.

Question 2

For virtual address `0x0000_0021_2345_6789` under SV39 paging, it can be divided into four parts: VPN2, VPN1, VPN0, and offset. The size of each part is 9 bits, 9 bits, 9 bits, and 12 bits, respectively. Thus, the VPN2, VPN1, VPN0, and offset are `0x084`, `11A`, `056`, and `789`, respectively.

(1)

The physical page number of the root page table is defined as the lower 44 bits of the `satp` register. Thus, the physical page number of the root page table is `0x000_0008_4000`. To find the physical address of the root page table, we need to multiply it by 2^{12}, which is the page size. Thus, the physical address of the root page table is `0x000_0008_4000` $\times 2^{12} =$ `0x00_0000_8400_0000`.
A second level page table is allocated at physical page `0x000_0008_6002`, and the `0x084`-th entry of the root page table points to this page table. The corresponding page table entry is `0x000_0008_6002` $\times 2^{10} =$ `0x0000_0000_2180_0800`.

(2)

The physical address of the second level page table is `0x000_0008_6002` $\times 2^{12} =$ `0x00_0000_8600_2000`, as calculated in the previous part.
A new third level page table is allocated at physical page `0x000_0008_6001`, and the `0x11A`-th entry of the second level page table points to this page table. The corresponding page table entry is `0x000_0008_6001` $\times 2^{10} =$ `0x0000_0000_2180_0400`.

(3)

The physical address of the third level page table is `0x000_0008_6001` $\times 2^{12} =$ `0x00_0000_8600_1000`, as calculated in the previous part.
A new page will be allocated for the requested virtual address, at physical page `0x000_0008_6000`. The `0x056`-th entry of the third level page table points to this page. The corresponding page table entry is `0x000_0008_6000` $\times 2^{10} =$ `0x0000_0000_2180_0000`.

(4)

The physical address corresponding to the virtual address `0x0000_0021_2345_6789` is `0x00_0000_8600_0789`.