LE16.1

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LE16.1.1: Page Maps

0.0/1.0 point (ungraded)

Consider a virtual memory system for the Beta that uses a single-level pagemap to translate virtual addresses into physical addresses. Assume 32-bit virtual (byte) addresses, a page size of 2^{12} (4096) bytes, and a physical memory of 2^{28} bytes.

1. The Beta produces 32-bit byte addresses, A[31:0]. Which of these bits should be interpreted as the virtual page number?

   address bits specifying virtual page: A[31 Answer: 31 **:** 12

   Answer: 12 **]**

   Explanation

   Each page is 2^{12} bytes, so the bottom 12 bits of the address are used to indicate the page offset. The rest of the address is used for the VPN. Since there we are told that the virtual addresses are 32 bits long, that means that bits 0-11 are the page offset, and bits 12-31 are the VPN.

2. Assuming each pagemap entry includes R and D bits, what is the total pagemap size in **bits**? You can express your answer as a mathematical expression, e.g., 10*(2^17).

   pagemap size, in bits: 18*(2**20) Answer: 18*(2^20)

   Explanation

   Since there are 20 bits in the VPN, There are 2^{20} entries in the page map, one per virtual page. The size of each entry must accomodate the physical page number (PPN) plus the dirty and resident bits. Since the physical memory is of size 2^{28} bytes, that means that the PPN is 16 bits, and each page map entry is 18 bits to allow for the dirty and resident bits in addition to the PPN. That means that the total size of the page map in bits is 18*2^{20}.

3. At any given time, what is the maximum number of entries in the page map that can have their R bit set to one? Assume that no virtual pages are mapped to the same physical page.

   Maximum number of page map entries with R=1: 2**16 Answer: 2^16

   Explanation

   The number of entries in the page map that can have their resident bit set to 1 cannot exceed the total number of physical pages. Since there are 2^{16} physical pages, that is also the maximum number of entries that can have R = 1 in the page map.

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LE16.1.2: Address Translation

0.0/1.0 point (ungraded)

The following table shows the first 8 entries in the page map. Recall that the resident bit is 1 if the page is resident in physical memory and 0 if the page is on disk or hasn't been allocated.

VPN	R	PPN
0×0	0	0×7
0×1	1	0×9
0×2	0	0×3
0×3	1	0×2
0×4	1	0×5
0×5	0	0×5
0×6	0	0×4

0×7 1 0×1

Suppose there are 1024 (2^{10}) bytes per page.

What is the physical address (in hex) corresponding to the virtual address 0×0F74? Please enter "--" if the address cannot be determined because the page is not resident.

0x: 0b74 Answer: B74

Explanation

VA 0×0F74 = 0b0000 1111 0111 0100. Since the bottom 10 bits are used for the page offset, the VPN = 0b000011 = 0×3, and the page offset = 0b11 0111 0100 = 0×374. Looking up VPN 3, we find that it is resident in main memory, and its PPN (physical page number) is 0×2. Concatenating the PPN with the offset bits results in a physical address of 0b 10 11 0111 0100 = 0xB74.

What is the physical address (in hex) corresponding to the virtual address 0×1678? Please enter "--" if the address cannot be determined because the page is not resident.

0x: -- Answer: --

Explanation

VA 0×1678 = 0b0001 0110 0111 1000. Since the bottom 10 bits are used for the page offset, the VPN = 0b000101 = 0×5, and the page offset = 0b10 0111 1000 = 0×278. Looking up VPN 5, we find that it is *not* resident in main memory and so the address cannot be determined.

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