Virtualization: VM Review (2 problems)



fetch 4K.

get PTE: 32K+4

fetch inst: 4K

execute: iond 8192 > +7

get PTE: 32K+B

fetch value: 20K

32768+4=7 32772

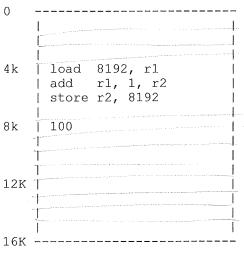
add: fetch 4K+4
get PTE: 32K+4
fetchinst: 4K+4

Here is some assembly code:

```
load 8192, r1  # loads value at memory (8192) -> r1
add    r1, 1, r2  # adds 1 to r1; result into r2
store r2, 8192  # stores r2 into memory (8192)
```

Assume each instruction takes up 4 bytes in memory.

Assume the program counter (PC) is set to 4096 (4k) when running the first instruction of this sequence. The virtual address space of this process looks like this (not to scale):



VA: 8192

10,0000 0000 0000

-181

R: 4

Assume this is a system with a hardware-managed, linear page table. The total size of this virtual address space is 16 KB. The page size for the system is 1 KB.

Each page table entry (PTE) looks like this:

Physical memory is of size 64 KB.

```
| valid | page frame number | protection bit | 1 bit | 6 bits | 1 bit |
```

(valid: 1->page is valid; protection: 1->read/write, 0->read only)

The PTBR for this process points to a physical address where the process's page table is located: 32KB.

The contents for this page table are:

0x 88 => 2 ready 1/000 100/0] 1/17=2 PFN=4

3214

MUMAN

Your task: List all the physical memory locations that are referenced during the execution of this three-instruction sequence, first assuming there is NO TLB, then assuming there is a TLB of infinite size.

1000/1010

101010011

PFN=20 Prot = read/write

## Assumptions:

- The page size is an unrealistically-small 32 bytes
- The virtual address space for the process in question is 1024 pages, or 32 KB
- Physical memory consists of 128 32-byte pages

Thus, a virtual address needs 15 bits (5 for the offset, 10 for the VPN).

A physical address requires 12 bits (5 offset, 7 for the PFN).

The system assumes a multi-level page table. Thus, the upper five bits of a virtual address are used to index into a page directory; the page directory entry (PDE), if valid, points to a page of the page table. Each page table page holds 32 page-table entries (PTEs). Each PTE, if valid, holds the desired translation (physical frame number, or PFN) of the virtual page in question.

The format of a PTE is thus:

```
VALID | PFN6 ... PFN0
```

and is thus 8 bits or 1 byte.

The format of a PDE is essentially identical:

The **Page Directory Base Register (PDBR)** is set to decimal **99**. (this means the page directory is held in this page) The problem: **Translate the virtual address 0x60B8**. What value do you get back from memory when you fetch this virtual address?

0: 1a 16 1a 10 17 09 06 11 16 1e 12 0c 07 10 1a 0c 15 06 1d 17 10 00 12 16 18 1c 00 17 0d 08 1e 02 page Oc 08 14 15 18 1c 14 1b 01 16 00 10 08 04 1e 1d 09 03 1a 1d 0c 17 1d 08 0a 0b 05 0d 17 1d 03 13 page page page page 7f 7f 7f bl 7f 7f 7f 7f 7f 7f page 7f 7f 7f 7f 7f 7f page 13 03 00 17 07 le 0f le 09 1d 09 02 0f 0d 0b 03 1b 06 0d 0c 01 14 06 0a 10 0d 0f le 0f 17 1d 1a page 8 : page 9: page 10: 15 02 0b 1d 13 00 08 15 0a 0f 18 11 18 12 18 08 15 12 0e 17 0f 0f 1b 19 17 11 05 04 09 11 1a 11 page Of 05 15 0d 05 1b 0c 08 16 1c 11 16 02 04 0f 15 09 07 08 02 0e 14 13 0a 0d 04 09 0e 17 16 0e 10 1e 04 14 0b 0f 06 14 07 0e 01 1e 0f 0e 16 0c 1b 00 19 0e 19 1d 1e 05 15 03 04 02 09 page Oc 1b 16 0f 14 11 17 1a 0f 1b 06 01 18 0a 0d 02 0d 02 03 0b 12 07 0c 07 07 07 0b 10 0c 19page 15 03 0c 09 1e 01 1b 10 02 1e 01 0d 02 16 03 06 16 0a 1c 0a 16 01 0e 00 0a 09 16 0d 15 01 14: 19 05 page 7f 7f page page 17: 16 18 0d 0a 0c 00 15 0a 1a 0c 17 14 03 17 05 00 14 09 1e 00 09 04 15 12 1e 1a 00 1b 19 1b 0c 16 page 18: 16 12 08 1a 01 13 0f 19 03 1a 0a 0f 06 02 0d 05 0d 05 02 0c 0c 0a 03 15 19 18 0c 05 02 07 0f 0a page page 11 01 15 11 13 03 09 05 1e 18 01 12 19 16 05 1a 18 17 08 11 11 15 17 0f 0f 1e 14 04 01 0c 07 16 00 00 00 00 page 20: 00 00 00 00 00 00 page 22: 0c 0c 1c 14 15 02 1c 15 08 1a 14 11 15 1c 12 09 1a 06 09 16 0b 12 06 0a 1b 06 0a 1a 18 13 10 05 page page 7f 7f 7f 7f 7f 7f 7f 7f 7f c6 7f a4 7f 7f 7f 7f 7f 7f page page 26: 17 15 02 09 0c 0f 0f 0e 08 17 01 11 1c 06 0e 1d 0c 15 15 0a 12 10 0c 1a 0c 1a 12 0a 1a 0b 1e 03 page page 27: 7f 7f 7f 7f page 28: 18 12 00 00 07 1b 19 1b 00 1d 04 0c 17 06 02 06 06 0b 1c 15 02 01 08 08 06 0f 18 17 01 1d 19 0b 29: 1b 1c 07 02 0a 13 0a 18 1b 12 00 04 03 1d 01 0d 02 1b 13 0b 17 08 0f 15 14 1e 1a 1a 17 01 02 06 page 30: le le 09 19 00 04 05 05 0e 07 le 16 0c 17 03 14 01 la 06 la 18 18 05 09 19 06 0e 05 17 08 0e 00 page page 32: 00 00 00 00 00 00 page page 7f f8 7f 7f eb 7f 34: 7f 7f 7f 7f 7f 7f page 35: 08 07 1e 06 10 0f 16 01 1e 0d 1a 05 09 19 1d 10 05 18 10 06 07 01 05 0b 15 0f 10 1c 0c 18 0c 1e page 36: 05 11 0c 0d 06 14 0e 1e 14 12 0c 0f 14 0e 1d 11 07 14 1a 1d 01 18 00 1b 15 0b 0a 01 06 1a page 37: 1d 1a 03 0e 0c 1b 1a 00 1e 1c 18 15 0e 0b 09 18 03 00 0f 04 0e 0f 1b 1a 0d 18 00 0a 07 0f 1b 1e page 38: page 39: page 7f a5 7f 7f 7f 7f 7f 7f 7f 7f 7f 91 7f 7f 7f 7f 7f 40: 7f 7f page 41: 14 07 1d 07 0e 02 05 11 01 0e 01 1e 0e 0c 02 14 1b 02 1d 08 11 0d 11 17 1e 13 14 03 00 09 18 0b page 42: 0e 03 09 09 17 1c 05 1c 0f 0d 01 16 17 14 19 17 0f 06 15 18 17 04 02 1d 14 08 01 1a 04 1c page page page 44: page 45: 7f 7f 00 00 00 00 00 page 47: 1d 17 10 19 09 05 1b 1b 1a 0c 1a 0f 1e 1b 18 03 0a 06 0a 07 0f 0f 11 05 1e 11 0f 05 06 1a 17 page 00 00 00 page 49: 02 19 1e 1a 19 05 0f 11 08 0c 04 0a 19 1d 1e 0b 12 04 18 06 01 13 07 1b 03 08 11 09 1a 13 04 12 page page 51: 04 0d 16 02 0e 0c 1c 04 1a 11 0f 1b 0e 18 00 16 1b 07 11 02 12 0a 08 1d 09 03 0c 0e 03 0c 08 16 page page 53: Oa Oe 19 15 05 1c 11 18 02 07 1a 12 16 1c Oa 14 12 12 0b 11 19 11 16 07 0b 01 04 11 1c 07 0e 1e page page 55: 19 0d 07 02 04 06 1d 16 0d 1d 02 1e 0d 0c 1b 0a 0f 06 17 11 0c 1c 08 18 12 13 11 0c 00 07 0f 09 page page 18 1d le 13 0f 0a 00 02 00 1b 07 0e 17 02 13 06 1c 1a 0c 11 1e 05 03 1c 0a 17 1c 0e 14 1e page page 00 14 08 1b 07 1d 06 1b 13 13 00 12 04 0e 04 12 1c 15 19 04 1b 1e 1b 14 19 18 00 0e 06 1c 0a page 7f 9c 7f 7f 7f 7f page page 62: 00 15 0d 0e 0d 13 11 05 09 16 15 18 1c 08 10 0b 0f 06 03 03 1e 05 11 17 1e 16 1a 08 0d 11 00 10 page 63: 0b 02 0e 1e 18 1a 1a 13 0d 0f 10 04 03 08 11 03 18 0e 0f 0c 02 19 11 0e 01 0d 0d 11 12 1b 07 07 page

page 65: 19 06 10 06 01 05 0e 16 0b 0a 1c 02 18 01 1e 0d 02 09 00 08 06 1b 16 07 0a 13 18 14 18 04 0e 18 page 7f 7f 7f 7f 7f 92 7f 7f 7f 7f 7f af 7f 7f 7f 7f 7f 7f 7f ec 7f 7f 7f a9 7f 7f page 00 page 00 00 68: 00 00 00 00 page 69: Oc 0e 11 17 04 01 1e 17 12 01 03 14 0d 09 1c 04 0b 05 14 1c 13 0e 0f 0c 07 18 1a 17 18 1e page 70: 09 09 14 07 13 1b 1a 09 0e 0f 08 0a 1e 00 04 14 02 09 18 1c 0b 06 1b 13 0f 0a 0a 09 17 0e 06 1b page page 72: 01 10 16 10 11 18 11 07 0d 0e 00 0f 0e 19 03 13 1b 05 02 0e 0a 08 11 19 18 17 13 1a 1a 16 page page 15 17 06 12 07 03 09 1c 1d 0f 13 05 08 14 08 17 19 0d 0c 05 07 19 08 02 16 74: 04 10 1c 04 1e 13 16 page 7f 80 7f 7f 7f df 7f c5 7f 7f 7f 7f 7f 7f 79 7f 79 7f 8d 75: page 04 06 0e 06 1a 16 15 15 0e 17 03 1b 1a 10 1e 06 05 10 1c 19 1d 18 02 02 19 01 0a 17 00 11 13 18 76: page page 78: page 79: 04 01 0a 0b 14 11 13 13 13 1e 0e 01 05 06 16 08 1e 17 19 0d 11 12 1a 08 12 13 1e 15 19 18 0b 16 page 80: 0b 16 11 00 14 0c 12 1d 08 01 1c 11 0b 17 02 06 01 02 0c 19 14 1e 04 17 03 14 0e 03 07 14 07 0b page page page page 84: 02 0d 0f 00 0f 1c 04 0b 06 10 16 14 04 16 13 1d 13 02 15 0a 01 18 11 0d 11 0e 18 1e 0a 16 1c 0b page page 86: 1d 14 0f 0a 16 00 1e 04 0d 00 0e 09 03 15 1b 00 06 0d 05 1b 11 0e 18 0a 16 0a 0b 0c 10 07 08 00 page page page 89: 0e 08 06 07 1b 10 07 19 12 1b 0e 0f 1d 0d 00 02 05 1d 0b 12 17 13 18 02 00 0b 02 07 17 0b 17 03 page 90: 15 04 0a 11 19 1c 10 le 09 02 16 02 1b 10 0d 14 01 0e 1b 04 0e 16 07 02 04 08 0f 1c 0ь 10 18 12 page 91: 12 13 07 04 17 10 0d 0e 18 19 0c 17 00 1b 00 1e 1e 12 1b 14 02 15 1e 16 06 0d 1a 18 06 19 0a 00 page page page 7f 7f 7f 7f ca 7f 7f 7f page 95: 18 1d 1b 14 10 02 1b 16 0b 07 0b 0f 19 0b 04 10 0a 17 1c 09 09 01 06 1d 02 1c 08 1e 0d 15 1e 11 page 7f 7f 7f 7f 7f 7f 7f cl 7f 7f 7f 7f 7f 7f 7f 81 7f 7f 7f 7f 7f 7f ed 7f 7f page 96: 7f 7f page page page 105: page 106: 09 0d 0a 02 08 11 03 03 03 07 1c 17 1d 13 1e 1c 1a 1a 0c 09 0d 04 03 06 1b 05 14 10 1c 0d 0a 10 16 Of 10 1a Od 14 O5 14 O2 1d 15 13 17 Oc Oe O9 15 19 1e 15 Oe O5 Oe 13 19 13 12 19 1e O6 1d Od page page 108: 0a 15 0d 0f 15 0d 09 04 0b 08 17 16 12 0b 14 08 16 13 01 1e 1b 1c 0b 07 19 11 1a 0f 19 04 0e 0d 0f 15 15 1d 18 17 0d 19 1d 15 02 14 0f 06 0b 18 14 0c 15 16 0d 1b 0d 05 1a 1716 18 page page 110: 17 04 0e 0b 1b 12 12 1d 0d 06 17 1e 03 11 17 13 0f 15 1d 18 1c 1d 02 1a 1e 18 06 05 13 14 12 13 page 111: 07 1b 17 0c 0a 11 12 05 0f 1d 0e 0c 1c 1e 1d 01 1a 06 0a 1b 03 04 08 06 0a 16 13 04 17 1c 12 05 page 112: 00 1b 08 0f 05 00 19 00 10 14 0c 08 1e 05 01 1c 00 1b 10 1d 00 08 1b 17 0d 01 1e 15 00 12 05 05 7f 7f 7f 7f 113: 7f 7f 7f 7f 7f 7f page 7f 7f 7f 7f 7f 7f 7f 7f page 115: 7f 7f 7f 7f 7f d6 116: Oc Oa 15 1d 1a Of Oc 14 O6 1e O8 O6 10 11 O3 O6 O4 O3 Ob O4 Of 1c 14 Oc O4 O7 O9 Oc O2 11 page 7f b5 7f page 117: page page 119: 7f 7f 7f 7f 7f ef 7f 7f 7f 7f 7f 7f 7f a3 7f page 120: 18 17 0a 0a 1c 09 0f 17 04 0f 07 1b 1b 06 01 11 14 13 0b 02 16 05 03 07 1a 13 0e 02 1b 0c 03 05 page 121: 17 02 11 0f 1c 10 1b 00 0f 18 00 17 14 18 0e 04 01 0f 19 0c 01 17 19 00 0f 1a 03 0a 1b 03 0b 0c page 122: 16 08 0e 0e 13 08 1e 0e 01 05 0a 19 0e 04 17 1b 14 04 15 0b 04 17 18 0a 1b 1d 1a 0e 10 17 17 07 page 123: 08 08 08 01 0e 1b 08 16 04 1d 0d 05 0f 1d 1a 08 11 1b 01 01 0a 00 0e 10 11 09 05 1e 1c 0c 05 0c page 124: 07 06 02 15 17 1a 15 1d 08 15 02 04 01 10 0d 0c 1b 0a 13 17 1c 16 1c 1d 18 0c 1d 1a 16 00 08 page 125: 1c 07 07 17 02 0a 02 02 07 09 1e 1a 10 02 1b 0b 18 0a 1e 0e 06 1c 18 05 08 0a 08 1c 09 13 09 09 126: 02 06 07 00 19 0f 1b 05 14 1d 0c 0d 0e 17 03 0c le 18 1a 0d 01 1e 09 17 0f 12 06 1e 18 03 19 16 page 127: 15 Of 19 Oc 06 01 Of 16 Od 09 1b 04 13 1b 15 09 1e 19 10 18 17 00 0b 0e 09 04 Oc 0f 05 09 01 17