Consider a simple system with segmentation in which virtual addresses are three decimal digits and physical addresses are also three decimal digits. A virtual address is composed of a one-digit segment id and a two-digit offset. E.g., for the segment table below, the virtual address 123 would be translated to physical address 223. Give the physical addresses for the following virtual addresses or other actions taken.

|  |  |  |  |
| --- | --- | --- | --- |
| Segment | Base Address | Length | Permissions |
| 0 | 500 | 80 | Read-only |
| 1 | 200 | 50 | Read and Write |
| X (other values are invalid) |  |  |  |

1. On a read operation, virtual address 040 is translated to physical address \_\_\_540\_\_\_\_.

2. On a write operation, virtual address 120 is translated to physical address \_\_\_220\_\_\_\_.

3. On a write operation to virtual address 000, what happens and why?

An exception is raised for trying to write into a read-only segment.

4. On a read operation to virtual address 085, what happens and why?

An exception is raised for trying to read beyond the segment’s length.

Consider a 10-page virtual memory with virtual pages numbered from 0 to 9, 10-word pages with words numbered from 0 to 9, a 4-page physical memory with page frames numbered from 0 to 3.

VPN P R W X M PFN

+-+-+-+-+-+---+ PTE fields:

0 |0|1|0|0|0| 0 | P - presence bit ( 0 = not present, 1 = present )

1 |1|0|0|1|0| 2 | R - read permission ( 0 = not allowed, 1 = allowed )

2 |1|1|1|0|1| 0 | W - write permission ( 0 = not allowed, 1 = allowed )

3 |0|1|1|0|0| 0 | X - execute permission ( 0 = not allowed, 1 = allowed )

4 |1|1|0|0|0| 1 | M - modified bit ( 0 = unmodified, 1 = modified )

5 |1|1|1|0|0| 3 | PFN - page frame number

6 |0|1|0|0|0| 0 |

7 |0|1|0|0|0| 0 |

8 |0|1|0|0|0| 0 |

9 |0|1|0|0|0| 0 |

+-+-+-+-+-+---+

Starting each time from this page table, what is the result of these virtual address accesses - give either the physical address or the system action (e.g., page fault or protection violation).

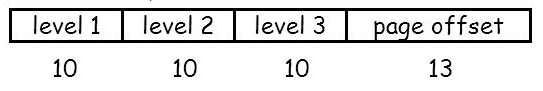
5. read 55 – Read to physical address 35.

6. write 44 – Exception raised because page is read-only/

7. read 33 – Exception raised because the page is not present in physical memory.

8. write 22 – Write to physical address 02 and set the modify bit.

One address translation scheme for the DEC Alpha used a 43-bit virtual address with three levels of page tables. The virtual address was divided into the following fields (the numbers are the field lengths in bits):



Answer questions 9-12 using powers of 2 for the address format above. Use bytes as the addressable units.

9. How big is a page in bytes?

2^(Offset bits) = 2^13 Bytes (8,192 Bytes).

10. If a page table entry is 8 bytes in size, how big is a page table in bytes?

2^10 entries \* 8 bytes/entry = 2^13 bytes = 8192 bytes = one page.

11. If a page frame number within a page table entry is 32 bits, what is the maximum size of physical memory in bytes?

2^32 pages \* 2^13 bytes/page = 2^45 bytes = 32TiB

12. Consider a data structure of 1 GiB. How many level-2 page table entries do you need to map the structure?

Level PTE maps 2^23 bytes.

2^30 bytes / (2^23 bytes/level-2 PTEs) = 2^7 level-2 PTEs = 128 level-2 PTEs.