4. (10 points) Page Tables and the TLB

Suppose you have a 64-bit virtual and physical address space with 4KB pages, an 8-word TLB, and 16 pages of physical memory. For simplicity, assume that the page table is in memory on page 15 and addressed through a Page Table Register (not shown below) and an entry for the page table is never put in the TLB. Also assume the following:

- An entry is added the TLB in the row with the lowest number that is not valid.
- When taking a page from the Free Page list, take the available page with the *lowest* page number.

For all addresses, the most significant 8 hex digits will always be 0, so just indicate the least significant 8 hex digits. Additionally, for this question, you **do not need to clear the reference bits**. Suppose the Free pages, the Page Table and TLB are as follows

Free pages: 1 3 5 7 9

Page Table

Index	V	D	R	Page (hex)
00000	1	0	1	00002
00001	1	0	0	0000A
00002	1	0	1	00008
00003	0	0	0	00007
00004	0	0	0	00003
00005	1	0	1	00004
00006	1	1	1	00006
00007	0	0	1	00005
00008	1	1	0	00000
00009	0	0	0	00001

TLB

Row	V	D	R	Tag	Page
0	1	0	1	00005	00004
1	0	0	0	00003	00007
2	1	0	1	00002	00008
3	0	0	0	00004	00003
4	1	0	1	00000	00002
5	0	0	1	00007	00005
6	0	0	0	00001	0000A
7	1	1	1	00006	00006

Suppose we have the following *sequence* of virtual memory accesses (all reads), starting with the Free pages, the Page Table and TLB above. For each memory access, write the corresponding physical address, and note if the physical page came from the Page Table (PT), the TLB, or caused a Page Fault (PF). In all cases, note the TLB row that is accessed (read from or updated). In your copy, make any updates to the page table and TLB; although this won't be graded, it will affect your answers to later addresses in the sequence.

Question continued on next page.

Memory Accesses: (addresses in hexadecimal)

Virtual Address	Physical Address	TLB/PageTable/ Page Fault	TLB Row
0x00000 5D8:	000025D8	TLB	4
0x00008 540:	00000540	Page Table	1
0x00007 A08:	00005A08	Page Fault	5
0x00004 710:	00003710	Page Fault	3
0x00008 110:	00000110	TLB	1
0x00001 360:	0000A360	Page Table	6