CS-UY 2214 — Recitation 12

Introduction

Complete the following exercises. Unless otherwise specified, put your answers in a plain text file named `recitation12.txt`. Number your solution to each question. When you finish, submit your file on Gradescope. Then, in order to receive credit, you must ask your TA to check your work. Your work should be completed and checked during the recitation session.

Problems

1. What is the page table and how is it used?
2. Why can the virtual address space be larger than the physical address space?
3. What is the TLB and how is it used? Why is it necessary?
4. Assume a computer has a CPU that uses 40-bit virtual addresses, has 32GB of physical memory, and each page is 4MB. Assume a single-level page table is used by the operating system and swapping is disabled (i.e. all pages are in memory, not on disk). Each memory cell is one byte.
   (a) How many bits are the page offset?
   (b) How many bits are the physical addresses?
   (c) What is the number of virtual pages? Leave your answer as a power of 2.
   (d) How many bits is the virtual page number?
   (e) What is the number physical pages? Leave your answer as a power of 2.
   (f) How many bits is the physical page number?
   (g) How many entries will be in the page table? Leave your answer as a power of 2.
   (h) Assume the metadata (dirty, protect, valid) for each page table entry is a total of 3 bits. What is the total size of the page table (including metadata!) in bytes?
5. Consider the following page table. Assume that each page is 8 bytes. Each memory cell is one byte.

Virtual page	V	Dirty	Protect	Physical page
0	1	1	0	2
1	1	0	1	7
2	0	0	0	
3	1	0	0	5
4	0	0	0	
5	1	1	0	10
6	1	0	0	8
7	1	0	0	6

Assume the following virtual addresses (represented in decimal) are accessed in the following order:

```
41, 26, 15, 59, 3, 48, 34
```

For each virtual address access, provide the virtual page number (VPN), and the corresponding physical page number (PPN), and the physical address; or indicate that a page fault occurs. If the mapped page cannot be written to, state that it is read-only. You may wish to use a table or spreadsheet to organize your response. Numeric values in your response should be in decimal.

6. Consider the following Translation Lookaside Buffer (TLB). It's a fully-associative cache with a size of 8 entries. The page size is 4 cells. Each memory cell is one byte.

Virtual page	V	Dirty	Protect	Physical page
2	1	0	0	18
17	1	0	0	2
6	1	0	0	4
12	1	0	0	12

Assume the following virtual addresses (represented in decimal) are accessed in the following order:

```
9, 72, 26, 17, 48, 74
```

For each access, state whether is it is a TLB hit or TLB miss. Provide the corresponding physical page and physical address, if possible.