EXERCISES -- VIRTUAL MEMORY

1. Given a computer with virtual memory and one cache level, with the following characteristics:
   - 20-bit Virtual Addresses generated by the processor.
   - 128KB Physical Main Memory with 32KB pages. LRU Replacement.
   - 1KB Physical Cache Memory. Direct-mapped and with a block size of 256B.

On this system we execute an application that randomly selects a song from a data base of songs. Songs occupy 8KB and their starting addresses are:

Song	1	2	3	4	5	6
Address	0x50000	0xF4000	0x66000	0x12000	0x40000	0x36000

a) Obtain the virtual and physical address format (from the point of view of the virtual memory and the cache memory).
b) Calculate in which virtual page (or pages) each song is included.
c) Given the following contents for the TLB and the cache memory. Which have been the latest played songs? Which is their physical address range?

Virtual page	Physical page
0x0A	1
0x0C	2
0x02	0
0x1E	3

TLB

Tag	Block
0x70	0
0x27	1
0x27	2
0x27	3

CACHE

d) The following sequence of virtual references is generated: 0xF40F5, 0x66000, 0x40040 y 0x51D04. Say which accesses generate a miss and which generate a hit, showing the evolution of main memory and cache memory.

2) Given a direct-mapped cache memory, virtually-indexed and physically-tagged, with the following address format:

Cache address format		
Cache tag	Cache index	Byte select
63:4	3:2	1:0

a) What is the size of the cache?
b) What is the size of the virtual memory pages?
c) How could we double the cache memory size without changing the address format?

3) Given a memory system with the following characteristics:
16MB Virtual Memory with an LRU replacement policy
Page size of 4KB
Main memory of 32KB
Physical cache of 8KB, with 64B blocks, set-associative with 2 blocks per set/and LRU replacement policy

Associative page table		
Page number	Frame number	Last access
100	0	0
101	1	1
200	2	2
201	3	3
300	4	4
301	5	5
400	6	6
401	7	7

a) Obtain the virtual and physical address format (from the point of view of the virtual memory and the cache memory).

Given the following program to execute:

```
int A[16384];
```

```
for (i=0; i<16384; i++)
    red+= A[i];
```

Assuming A starts in virtual address 0x100000 and **red** variable is stored in a register:

b) How many virtual pages are used?

c) How many hits and misses occur?

4) Given a computer with paged virtual memory and a cache memory, with the following characteristics:

- 4GB Virtual Memory system.
- 64MB Physical Memory with 8MB pages, which uses a FIFO replacement policy.
- 256KB direct-mapped Physical Data Cache, with a block size of 64KB.

The disk stores 20 photo albums (Alb1 ... Alb20). It is executed a program which randomly selects one of the albums, and shows in the screen random photos one after the other. Each album occupies 2MB and each photo 64KB. Alb1 starts in virtual address **0x02800000, and the other albums are stored sequentially after Alb1.**

a) Obtain the virtual and physical address formats (both for the memory and for the cache).

b) Obtain the albums which are stored in Main Memory, given the following contents of Page Table, TLB and $.

Tabla Páginas

Nº fila	V	FIFO	Nº pag. física
.	0	.	.
.	.	.	.
.	0	.	.
5	1	1	6
6	1	0	0
.	0	.	.
.	0	.	.
9	1	2	1
.	0	.	.
.	.	.	.
.	0	.	.

TLB

FIFO	V	Nº pag. virtual	Nº pag. física
0	1	5	6
1	1	9	1

Caché

Etiqueta	Bloque
0xD0	0
0xD5	1
0xD0	2
0x27	3

All data is expressed in decimal, except the Cache Tag. V is the valid bit. The page to replace corresponds to the one with a FIFO bit equal to 0.

c) What are the initial physical addresses for the albums of the page that was brought to Main Memory in the last place?

d) The photo at virtual address 0x03400000 is accessed. Say the order of accesses, whether there is a miss or a hit, and the final content of the tables.