Introduction To Computer Systems
Ex. 4 Pen and Paper

1 Memory hierachy

1.1 Basic question

1) Why do memory hierachies work?

2) List three types of cache misses.

1.2 Read-Write transaction

1) Suppose there is no latency, and all processes are executed sequentially without being overlapped. Express the time it takes for memory read transaction and memory write transaction in traditional bus structure with the following given symbols.

Description	Symbol
Time it takes for the value to be placed on the memory bus	t_place
Time taken to read the value to the memory bus	t_read
Time it takes to place a value in the register	t_reg
Time taken to store the read value in Main Memory on the Memory Bus	t_mem

Table 1: Descriptions of symbols

1.3 Disk capacity / Access time calculation

1) Calculate disk capacity by using the following information.

```
<Information of disk>
- 8 platters per 1 disk
- 400,000 tracks per 1 disk
- 20,000,000 sectors per 1 platter
- 4,096,000,000 bytes per 1 surface
- 10,000 tracks per 1 surface
```

2) Calculate disk access time by using the following additional information. Assume that the disk has same information of problem 1).

```
<Additional information of disk>
- Rotational rate : 3600RPM
- Average seek time : 5ms
```

1.4 Locality

1) Briefly describe temporal locality and spatial locality.

2) Fill in the blank so that the function scans the 4-d array with a stride-1 reference pattern (and thus has good spatial locality)?

```
int sum_array_4d(int arr[M][M][M][M])
{
    int i, j, k, l, sum = 0;
    for(i=0;i<M;i++)
        for(j=0;j<M;j++)
            for(k=0;k<M;k++)
                for(l=0;l<M;l++)
                    sum += a[ ][ ][ ][ ]; //fill in the blanks
}
```

2 Virtual Memory

2.1 VM as a tool for caching

1) Briefly describe why we use virtual memory.

2) The table below is a initial state of the page table. Suppose that the index of physical memory is 0 to 3, and the index of virtual memory is 0 to 7. When a request comes in in the following order, find the page table after the last request is processed.
* when the index of the virtual memory is small, it is assumed that the priority of eviction in the physical memory is high.
** PPX means Index X in physical memory, VPX means Index X in virtual memory

valid	Physical Page number or disk address
1	PP2
1	PP0
0	VP3
1	PP1
0	null
0	null
1	PP3
0	VP7

Table 2: Page Table

```
<Request Order>
1. Allocate VP4
2. reference VP2
3. reference VP4
4. reference VP7
5. allocate VP5
6. reference VP5
```